AGRICULTURAL ENGINEERING

Published monthly by the American Society of Agricultural Engineers

Publication Office, Bridgman, Michigan. Editorial and Advertising Departments at the Headquarters of the Society, Saint Joseph, Michigan

Subscription price to non-members of the Society, $3.00 a year, 30 cents a copy; to members of the Society, $2.00 a year, 20 cents a copy. Postage to countries to which second-class rates are not applicable, $1.00 additional. Entered as second-class matter, October 8, 1925, at the post office at Bridgman, Michigan, under the Act of August 24, 1912. Additional entry at St. Joseph, Michigan. Acceptance for mailing at the special rate of postage provided for in Section 1103, Act of October 3, 1917, authorized August 11, 1921. The title AGRICULTURAL ENGINEERING is registered in the U. S. Patent Office.

OSCAR W. SJOGREN, President **RAYMOND OLNEY, Secretary-Treasurer**

Vol. 8 JUNE, 1927 No. 6

CONTENTS

FACTORS INFLUENCING SOIL MOISTURE REGULATION 135
By R. W. Trullinger

THRESHING ATTACHMENT FOR GRAIN BINDERS 139
By J. C. Wooley

INDIANA'S FARM ELECTRIC CAR 140
By Truman E. Hienton

RURAL ELECTRIFICATION AS AN OPPORTUNITY FOR THE AGRICULTURAL ENGINEER 141
By E. A. White

ELECTRIC CURRENT CONSUMPTION ON SEVEN NEW HAMPSHIRE FARMS 142

FARMS RECEIVING ELECTRIC SERVICE 142

THEORETICAL CONSIDERATIONS OF THERMAL CHARACTERISTICS OF DAIRY EQUIPMENT STERILIZERS 143
By A. W. Farrall

AN INEXPENSIVE DRAWBAR DYNAMOMETER 145
By E. C. Sauve

A THOUSAND HOURS USEFUL LIFE FOR FARM EQUIPMENT 147
By Claude K. Shedd

THE DRAINAGE OF LOW PRICED AGRICULTURAL LAND 148
By Lewis A. Jones

THE MISSOURI TERRACING FRAME 149
By J. C. Wooley

THE ENGINEER IN AGRICULTURE 150
By Arthur Huntington

ENGINEERS AS LEADERS AND PIONEERS IN THE NEW CIVILIZATION 153
By Dexter S. Kimball

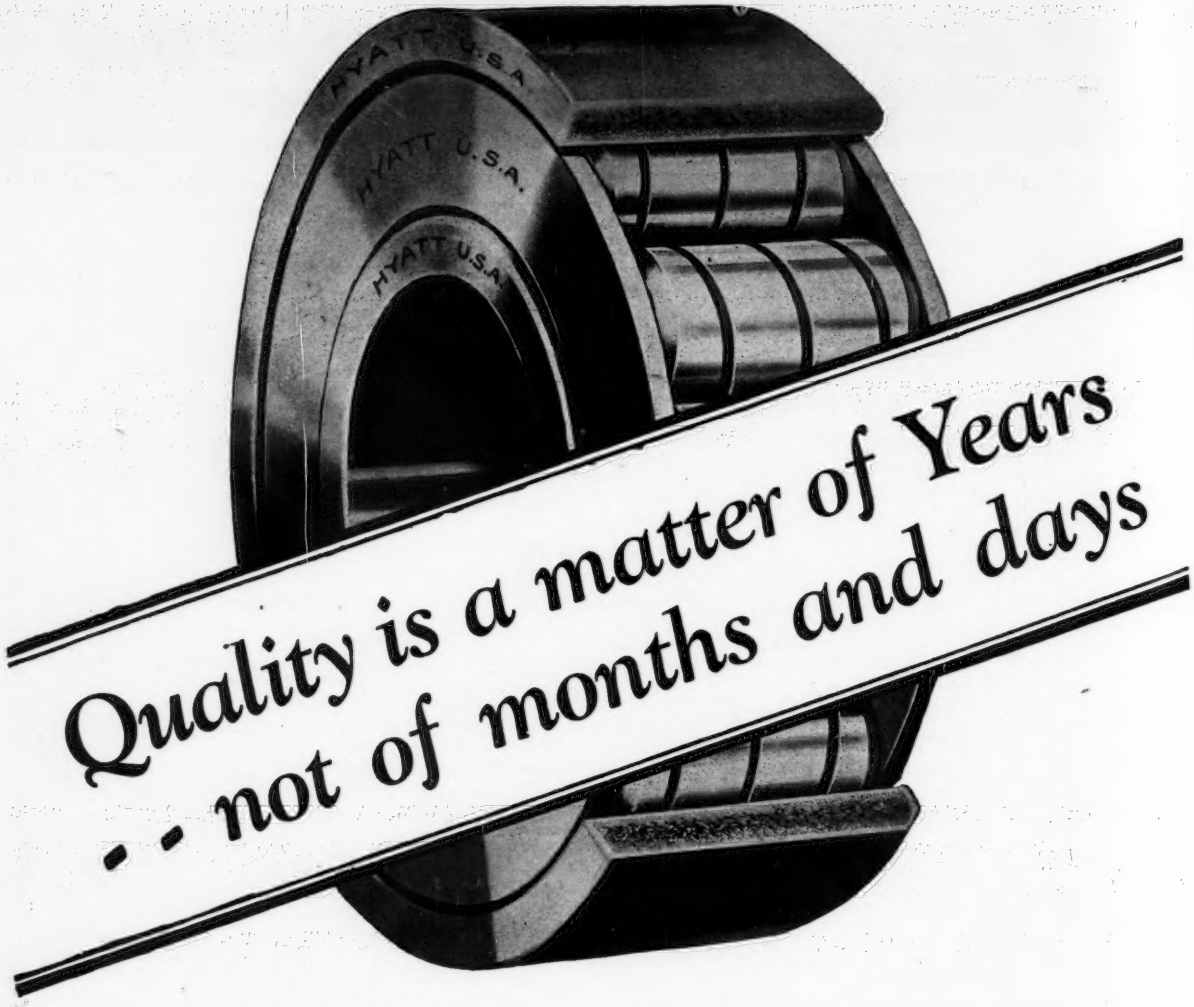
RESEARCH IN AGRICULTURAL ENGINEERING 155
—Kinematics and Dynamics of the Wheel-Type Farm Tractor
By E. G. McKibben

IMPORTANT FACTORS IN FLOOD CONTROL 160

AGRICULTURAL ENGINEERING DIGEST 161

EDITORIALS 162
—To Legislate or Not to Legislate
—Farm Features for Farm Homes
—Flood Control
—"Rub a Dub Dub"
—The Horicon Marsh in a Hundred Words
—From India

A.S.A.E. AND RELATED ACTIVITIES 164



Quality is a matter of Years
. . not of months and days

Hyatt Roller Bearings are used by farm machinery manufacturers whose essential interest is in upholding the time-honored quality of their products. The name "Hyatt" die stamped on each bearing is assurance that bearing satisfaction is built into your equipment.

HYATT ROLLER BEARING COMPANY
Newark Chicago Detroit Pittsburgh Oakland

HYATT
ROLLER BEARINGS
PRODUCT OF GENERAL MOTORS

"Please mention AGRICULTURAL ENGINEERING when writing to Advertisers"

AGRICULTURAL ENGINEERING

The Journal of Engineering as Applied to Agriculture

Vol. 8 JUNE, 1927 No. 6

Factors Influencing Soil Moisture Regulation*

I. Soil Moisture Forms, Absorption, and Retention

By R. W. Trullinger[1]

THE regulation of soil moisture to meet the requirements of growing crops, whether by irrigation, drainage, cultivation, or other processes, is a matter of considerable concern wherever crop plants are grown. Water in soils serves as a direct source of supply of moisture to crop plants. It also serves as a solvent of plant nutrients and as a medium for their distribution throughout the soil, especially in the rooting zone of plants. Colebatch (1)[2] at the Department of Agriculture of South Australia and Harris (2) at the New York (Cornell) station both showed, for example, that the soil moisture supply exerts an important influence on the effectiveness of fertilizers.

Regardless of the nature of the soil or climate in which they are grown, it appears that crop plants require rather definite quantities of moisture to permit their optimum growth and maturity. They also require a normalcy of other growth factors, such as temperature, air supply, nutrient supply, and the like. In order for plants to thrive, therefore, the soils in which they are grown must be able to supply the required moisture in available form and in proper distribution. They must also be able to maintain a normalcy of other growth conditions, the majority of which are apparently linked more or less closely with normalcy in the supply and distribution of moisture.

Soil is, however, known to be a highly complex material, which, when capable of supporting plant life, is dynamic in nature. Many of the dynamic properties are known to be governed by certain physical and physicochemical laws. It seems likely therefore that the manner of existence of water after it enters the soil is considerably different from that of its existence in the open. It is undoubtedly subject to many influences in the soil which it does not encounter in the open atmosphere and which in many cases must largely determine its availability to plants.

A clear knowledge of the manner of existence and functions of water in soils from the standpoint of the actual requirements of crop plants therefore seems highly desirable. This has long been recognized by agronomists and soil technologists, and also by some agricultural engineers, and there is an extensive record of investigations on soil moisture and the factors governing its functions. It seems, however, that these investigations have been disconnected in many instances, and the available results are fragmentary and inclined to be either in abstract terms or in terms of purely agronomic considerations. It appears that relatively little of a tangible and connected nature is known about the principles governing the action of water in and through soils which provides a sound basis for drainage, irrigation, or tillage practices, or for the development of the corresponding structures and machinery. Everything indicates that these practices are at present based, to a large extent at least, on tradition and the purely speculative results of service experiments.

Quite naturally this has raised a question in the minds of agricultural engineers as to the possibility of utilizing the results of soil technological studies for the development of rational soil moisture regulation processes. This tendency has become more frequent in recent years owing to the increasing cost of agricultural production, until a point has been reached at which it seems necessary for the soil technologist and agricultural engineer to join forces in an effort to solve the soil moisture regulation problem and place it on a practical engineering as well as agronomic basis.

It was therefore deemed advisable, as a contribution to this movement, to go back over the investigations of soil moisture by both soils technologists and agricultural engineers at some of the leading research institutions during the past twenty years in an effort to determine what knowledge of the subject of a substantial and tangible nature exists, and to what extent it may be pieced together and made to logically bear on the development of soil moisture regulation practices. An attempt will be made in this paper to throw some light on the available knowledge of the forms in which water is present in soils and on some of the factors influencing its absorption and retention. Subsequent papers will deal with the factors influencing moisture losses, availability of soil moisture, the movement and distribution of moisture in soils, and soil moisture regulation measures.

FORMS OF SOIL MOISTURE

It seems likely that total water content of soils presents an inadequate basis for procedure in dealing with the regulation of soil moisture from the standpoint of crop requirements. All of the soil moisture is not necessarily available to plants. In fact Bouyoucos (3) at the Michigan Experiment Station found that several different forms of moisture may exist in some soils with reference to its availability to plants. This indicates the necessity, therefore, of considering the different forms of moisture which remain normally in the soil against the influence of gravity. Fisher (4) at the University of Leeds found in this connection that water in soils is held as capillary or interstitial water present as wedges between the soil grains, and as imbibitional water which is associated in some way other than interstitially with the clay particles and with the colloidal coating of the soil grains. It seems likely that some of this water is active and some inactive from the standpoint of plant requirements.

Free Water. Bouyoucos and also Wintermeyer (5) of the U. S. Department of Agriculture found that when water in a soil is frozen, the total water content is seldom involved. A portion was found to freeze for the first time at about —1.5 degrees C., and this was designated as free soil water. Presumably this involves the greater part of the capillary or interstitial water which is held and moves by film forces.

Unfree Water. McCool and Weidemann (6) at the Michigan station found further that soils are capable of holding appreciable amounts of water in such a condition that it

*First article of a series under the general title "Factors Influencing Soil Moisture Regulation." These articles are intended to lay a foundation for a program of research in the regulation of soil moisture. Since there has been considerable agitation of this subject in connection with drainage and irrigation practices and also in connection with the development of cultivating and tillage machinery, it would seem that the material presented in these articles is particularly timely. It seems likely that a more accurate knowledge of the manner of existence and functions of water in soils and of the ways in which this water may be regulated should provide a definite basis for the development of drainage and irrigation practices and structures and of tillage and cultivation methods and machinery to meet the requirements of certain soils growing certain crops.

[1]Specialist in agricultural engineering, Office of Experiment Stations, U. S. Department of Agriculture. Mem. A.S.A.E.

[2]Numbers in parenthesis refer to the list of references that follows this article.

does not function as a solvent, and is made unfree. This water seems to be both physically adsorbed and chemically combined.

Bouyoucos (3) and Wintermeyer (5) subclassified the unfree water into capillary or adsorbed water and combined water. They differentiated between these two forms by showing that the capillary water freezes at from —4 to 78 degrees C., while the combined water does not freeze at all even at temperatures below —78 degrees C. Thus it seems that some of the capillary water may become inactive for a time at least. Bouyoucos (7) showed further that the amount of water which soils are able to render unfree does not vary with the different moisture contents but appears to remain constant, at least so long as the soil is otherwise unchanged. However, Wilsdon (8) of the Agricultural Research Institute at Pusa established the variation of the combined water in the colloid of a soil with the osmotic pressure of the soil solution.

Hygroscopic Water. Lobanov (9) of the Moscow Agricultural Academy found that when the soil moisture content sinks below the socalled inactive supply it becomes entirely unavailable to plant roots. The inactive moisture was considered to be about equal to the maximun hygroscopic moisture in amount and is independent of the conditions of transpiration and absorbing surfaces. The wilting coefficient of plants was found to vary from 1.5 to 3 times the hygroscopicity of the soil.

Bouyoucos (10) found that the per cent of the water content in all soils that fails to freeze corresponds closely to the wilting coefficient. A more or less direct relation is thus established between the unfree water in soils and the hygroscopic water.

Alway (11) at the Nebraska station found, however, that even some of the water below the hygroscopic coefficient of soils may be available for the maintenance of the life of certain perennial desert legumes. In general the hygroscopic coefficient or the wilting coefficient have been satisfactory as bases for determining the available moisture in soils. It was found, in the case of ordinary dry land soils, in which the water table is at a considerable depth below the surface, that the maximum amount of soil water available to plants for growth and life maintenance is approximately equal to the free water. This is considered to be the difference between the total water and that represented by the hygroscopic coefficient in those portions of the soil and subsoil occupied by the plant roots.

Thomas (12) at the Utah station found that, when comparable vapor pressure-moisture curves of a series of soils ranging from fine sands to tight clays and from highly calcareous to highly siliceous materials, were considered, all of the soils could be divided into two groups in each of which the relative amounts of hygroscopic water remained nearly constant over a range of from 10 to 95 per cent of the vapor pressure of water. Changes in the slope and position of the curves due to wetting and drying did not change the relative hygroscopicities. These ratios of the hygroscopic water agreed closely with the ratios of the surfaces of the particles larger than from about 0.1 to 0.2 micron radius.

Gardner and Israelsen (13) at the Utah station found that if the angle of contact of the surface of contact of water and soil grains is zero, a soil kept in a dark chamber can not be in equilibrium with saturated water vapor without becoming completely saturated with water. This leads to a new interpretation of the so-called hygroscopic coefficient, in that it becomes a measure of the moisture condition at equilibrium between soil and water in the presence of light, but this moisture condition changes with the intensity of the light. Some experimental evidence was accumulated indicating that the angle of contact involves the curvature of the surface of separation of the liquid and solid phases.

Thus it appears that hygroscopic water and otherwise inactive water exist in soils more or less without regard to total moisture conditions, and wholly in addition to that water which is free to act as a solvent of nutrient material and as a source of available moisture to plants. The significance of this becomes more evident when the occurrence of the different forms of moisture in various soil types is considered, and especially when the influence of environmental factors other than the nature of the soil is known.

The evidence available in this connection indicates that the quantity of water which is inactive or unfree varies in different classes of soils. Bouyoucos (10) found that this quantity varied from 2 per cent in quartz sand to 80 per cent in clay, increasing, therefore, from the simple and non-colloidal types to the complex and colloidal types of soil. Bouyoucos (3) found further, however, that repeated freezing and thawing causes some of the unfree water to become free. On the other hand, the influence of temperature in this connection is indicated by the finding of Alway (14) at the Nebraska station that the amount of hygroscopic moisture in soils tends to increase with a rise in temperature.

Blanck (15) at the University of Gottingen found that the hygroscopicity of sandy loam soil was reduced by caustic lime. The effect of this material was greater than that of any lime materials used for this purpose, and precipitated carbonate had the least effect.

Thus it seems that while the heavier and more complex soils are likely to contain a greater percentage of inactive water than the lighter soils, outside influences such as weather or chemical or other treatment may alter this situation somewhat. The factors influencing the absorption and retention of moisture by soils and determining the normally active soil moisture capacity seem therefore to assume considerable significance.

FACTORS IN THE ABSORPTION OF MOISTURE BY SOILS

Soils under normal conditions may vary quite widely in their ability to absorb moisture. Patten and Gallagher (16) of the U. S. Department of Agriculture found that the amount of water absorbed from water vapor by various types of soils increases with the humidity but not in a simple mathematical relation. The velocity of absorption decreases regularly as absorption proceeds. Presumably both internal and external factors of a rather definite nature strongly influence this phenomenon.

Mechanical Properties. Petit (17) at the French Institute of Agronomy established that the size of soil aggregate apparently has no influence on absorptive power for moisture when the grains are greater in size than 2mm. It was found, however, that when the grains were less than 2mm. in size the absorptive capacity of soil for moisture increased rapidly with the degree of fineness. Sedimentation of fine-grained soil appeared to reduce its absorptive capacity for moisture considerably.

Oden (18) at the Central Swedish Experimental Station, when working with clay soils, found that the coarser the clays the less water was held, while the stiff, strongly plastic clays absorbed larger quantities of water. The conclusion was drawn that hygroscopicity is dependent not only on the surface development but also on the chemical nature and constitution of the clay. Widtsoe and McLaughlin (19) at the Utah station found that the hygroscopicity of deep soil of uniform physical and chemical composition depended largely on the content of clay and other colloidal substances.

Mendes (20) at the Agricultural College of Brazil found that soils containing a high percentage of fine clay particles, such as the red soils, fixed more hygroscopic moisture than other soils. The hygroscopicity increased as the pressure of stratification increased, but not proportionally. It was directly proportional to the amount of exposed surface area of the soil, and this was concluded to be the principal factor influencing hygroscopicity.

Sen and Amin (21) of the Department of Agriculture of India found that nine widely varying soils absorbed quantities of moisture which were exponential functions of their contents of clay. The equation $\text{Log } W = a + K \log C$ signifies this phenomenon, in which W represents the milligrams of water absorbed by one gram of dry soil, C indicates the percentage of clay as determined by mechanical analysis, while a and K are constants. The determination of the hygroscopic capacity of the ordinary cultivated soils was found to yield a useful single valued expression of the relative fineness of texture.

Patten and Gallagher (16) found that the absorptive capacity of soil for water vapor is generally higher the finer the texture of the soil and the greater the content of humus.

Novak (22) at the Imperial Technical Academy at Prague found, however, that soils having the same hygroscopicities may have entirely different mechanical compositions. No

Relatively little of a tangible and connected nature is known about the principles governing the action of water in and through soils which provides a sound basis for drainage, irrigation, or tillage practices, or for the development of the corresponding structures and machinery. . . . . It seems necessary for the soil technologist and agricultural engineer to join forces in an effort to solve the soil moisture regulation problem and place it on a practical engineering as well as agronomic basis.

regular relation was established between hygroscopicity and the smallest hydraulic value on the scale indicating the content of the finest particles capable of sedimentation. Likewise no valid general relation was established between hygroscopicity and the content of raw clay or of particles of a size smaller than 2 microns. It was found, however, that for practical purposes a high proportion of the particles capable of sedimentation or a high content of raw clay is accompanied by a high hygroscopicity, especially in soils free of humus.

Puri, Crowther, and Keen (23) at the Rothamsted Experimental Station showed that the absolute amounts of water absorbed by a characteristic series of soils at definite high humidities increased with increasing specific surfaces and were markedly affected by previous treatments known to disintegrate the soil.

These results seem to indicate that mechanical composition of soils has a strong influence on their absorptive powers, especially in the fixation of moisture in the inactive state. It also seems evident, however, that there are other influencing factors.

Physicochemical Properties. Bouyoucos (24) established a relationship between the combined or unfree water and the heat of wetting of soils, both factors tending to vary in the same order in most of the soils examined. This is significant in view of the growing tendency to use the heat of wetting as an indication of the colloid content of soils. In subsequent work Bouyoucos (25) found this relationship to be close and consistent. However, no relationship was established between the heat of wetting and the moisture equivalent or between the unfree water and the moisture equivalent.

Mason (26) at the Imperial Department of Agriculture of the West Indies established the existence of a high degree of correlation between the colloid content of seven soils and their moisture residues at permanent wilting. Keen (27) at the Rothamsted Experimental Station showed, however, that the colloidal material in soil exercises a profound effect on the moisture relations over a wide range of moisture content, which suggests that the influence of the colloidal material is not limited to the unfree water. Mendes (20) found that hygroscopicity increased in poor soils as the contents of organic matter, kaolin, and of such colloids as aluminum and ferric hydrates increased but not proportionally. This suggests that there are limits to the conditions of hygroscopicity and of unfree or inactive water in soils so far as the absorbing influence of colloids is concerned.

Sen and Amin (21) showed that the specific action of the inorganic and organic gels in soils with reference to moisture absorption is usually masked, the major part of the colloids present in ordinary soils being of similar effectiveness. The difference in their nature is, however, manifested in the case of unusual soil types.

Temperature. Patten and Gallagher (16), Sen and Amin (21), Puri, Crowther, and Keen (23), and Bouyoucos (28) all found that the capacity of soils for the absorption of moisture decreases with increasing temperatures, especially above 20 degrees C. and particularly in the lower relative humidities.

It appears quite likely, therefore, that some features of the mechanical composition and physicochemical properties of soils and certain external factors have a marked influence on the absorbing and fixing powers of soils for moisture, especially that which becomes inactive for the time being. The extent of this influence on the free water, i. e., that water which is available to plants but which can not be easily lost by gravity may perhaps be better determined by a consideration of the moisture retaining powers of the soil.

FACTORS IN MOISTURE RETENTION BY SOILS

Absorption is probably a necessary preliminary factor to the retention of some moisture by soils. In addition other factors seem to take a hand to the extent that while moisture may be free for use by plants, it cannot readily escape from soils under normal conditions.

Some doubt seems to exist as to proper standards for judging the retentive power of soils for moisture. Israelsen (29), in studies at the California station, found in this connection that correlations between the moisture equivalent and the maximum amounts of water in soils after irrigation showed a gratifying agreement, and suggested that the moisture equivalent may be made the basis for judging maximum capillary capacities of soils. Bouyoucos (25) found that some of the fine-textured and colloidal soils may contain considerably more moisture than that indicated by their true moisture equivalent. Harding (30) of the U. S. Department of Agriculture, however, established a fairly consistent relationship between the moisture equivalent and the various moisture properties of soils, which, however, was apparently not linear except in the case of the wilting point. Alway and Russel (31) at the Minnesota station found that with silt loam soils from thirty virgin fields the hygroscopic coefficient may in most cases be calculated from the moisture equivalent with sufficient accuracy to permit its use in soil studies.

At any rate the manner in which the moisture equivalent of soils is determined suggests that it may be used at least as a measure of the minimum retentive powers of soils for moisture until a better method is advanced. Briggs and McLane (32) of the U. S. Department of Agriculture concluded, in fact, that by means of the moisture equivalent measurement it is possible to reduce the moisture content of a soil until it is no greater than that of the soil under favorable field conditions, and to thus determine the retentive power of different soils for moisture when acted upon by the same definite force, comparable in magnitude to the pulling force to which the soil moisture is subjected in the field.

Naturally the capacity of soils for moisture is also an important factor in retention. Shaw (33, 34) at the California station recognizes the existence of normal and maximum moisture capacities of soils. The normal capacity represents the minimum amount of water retained by absorption and film forces when the water is free to move downward through a mass of uniform soil. The normal moisture capacity is, for medium-textured soils, approximately the same as the moisture equivalent. At normal capacity the moisture is readily available to plants, but is not free to move under the normal film forces existing in the soil. At maximum moisture capacity the water is free to move under normal film forces.

With these points in view and their connection thus established, the factors influencing moisture retention may be discussed perhaps a little more intelligently.

Mechanical Properties. The mechanical properties of soils seem to materially influence the retention of moisture. Israelsen and West (35) at the Utah station showed that the actual capacity of a given soil for moisture depends upon its texture and structure. Sandy or gravelly soils were found to retain the smaller amounts and clay loam soils the larger amounts. Israelsen (29) found further that the percentage of pore space filled with water immediately after irrigation increases with the increase in fineness of the soil texture. Powers (36) at the Oregon station found that only the heavier classes of normal soils were capable of retaining as much as 2 inches of usuable water in the surface acre-foot. The coarser soils irrigated retained only 0.5 inch for each foot of depth, while peat retained from 3 to 4 inches.

Juritz (37) of the South African Department of Agriculture concluded that the factor which controls the moisture content of soils is the relative size of the soil particles and considered texture to be an index of the behavior of soil in relation to moisture in the field. Puchner (38) at a Bavarian agricultural experiment station found that with the exception of mineral soils the water-carrying capacity of soils was generally considerably larger when the soils were puddled than when they were in the loose condition. Leather (39) of the Department of Agriculture of India found that the water-retaining power of a soil after drainage has ceased is closely related to the total surface possessed by the solid particles.

Alway and McDole (40) at the Nebraska station found that maximum water capacity has little significance as a direct index of the moisture retentiveness of a soil. The moisture content of the moistened layers of finer textured soils apparently fell much more rapidly than that in layers of coarser soils, while in the coarser soils the moisture content varied from three to ten times the hygroscopic coefficient. Equilibrium was practically attained at the end of five days in the finer textured soils, while in the coarser ones this was far from being the case. The coarser the soil, the more slowly was equilibrium reached.

Alway and McDole (41) found further that the water-retaining capacity of loam soils bore a somewhat closer relation to the moisture equivalent than to the hygroscopic coefficient. Coarse sands behaved differently from the loams in this respect. The ratio of water-retaining capacity to hygroscopic coefficient in the surface 6 inches even three months after a one-inch application of water was as high as 6 or 7, while in the second foot it was only one. Fine sands occupied a position intermediate between the loams and coarse sands in this respect. Briggs and McLane (32) found that the moisture equivalents of over one hundred samples of type soils, using a centrifugal force of about three thousand times gravity varied from 3.6 per cent in the coarser sandy soils to 46.5 per cent in heavy clay subsoil.

Middleton (42) of the U. S. Department of Agriculture established a direct relationship between the moisture equivalent and the percentages of sand, silt and clay in soils as determined by mechanical analysis. The presence of considerable amounts of organic matter tended to increase the moisture equivalent and to disturb the relation between it and the mechanical analysis. Monroe (43) at the California station found a direct relation between the amount of organic matter present in soil and the moisture equivalent. However, there was no marked relation between the latter and the condition of the organic matter whether raw or thoroughly decayed. The presence of clay in the soil had a much larger unit effect on the water-retaining capacity than did the presence of organic matter.

These results seem to indicate that the amount of water which can be retained by soils under certain imposed conditions is strongly influenced by their texture and structure. Apparently mechanical analysis gives some indication of their tendencies in this connection so long as the situation is not unduly complicated by the presence of an excess of organic matter.

Physicochemical Properties. Bradfield (44) at the Missouri station established a direct relation between specific surface and moisture equivalent of soils. Particles larger than 5 microns in diameter were not appreciably affected by drying or even by ignition. Air-drying of particles from 0.025 to 1 micron in diameter, however, resulted in the formation of aggregates which had practically the same moisture equivalent values. Blanck (45) at the University of Gottingen found that the capacity of air-dry soils to retain moisture was less when fertilized than when unfertilized with the exception of those receiving lime. Soils treated with sodium nitrate retained the least moisture.

It seems likely that the physicochemical properties of soils also influence their ability to retain moisture. Apparently both mineral and organic colloids are active in this respect and the effect of external chemical treatment on this action seems evident. A more specific knowledge of the nature and extent of the influences, especially of the two different kinds of colloids, seems desirable.

SUMMARY

The above analytical summary probably does not by any means cover all of the work which has been done on soil moisture forms, and on the factors influencing and governing the absorption and retention of moisture by soils. It is sufficient, however, to indicate the likelihood that moisture does exist in soils in different forms with reference to its activity and availability to plants. Apparently the occurrence of these forms of moisture is governed in some instances and influenced in most by the texture and structure of soils, by their physicochemical composition and by certain external factors such as temperature. The exact nature and extent of these influences remain to be explained.

Perhaps the most striking and definite indication is that the factors determining the existence of soil moisture forms also influence the absorption and retention of moisture by soils. However, the state of the available knowledge of these phenomena seems yet so incomplete and disconnected as to leave considerable doubt as to the exact nature and extent of the influences of these factors. The phenomena of soil moisture forms and of the absorption and retention of moisture by soils can not be controlled in practice until they are thoroughly understood. It seems likely that this understanding can be obtained only by an orderly and connected study of the problems involved, many of which are indicated in the above discussion. Since both have contributed to the available knowledge, a joining of forces by agricultural engineers and soil technologists in a study of this nature might be desirable.

List of References

(1) Colebatch, W. J. Soil water in relation to plant growth. Jour. Dept. Agr. So. Australia, 18 (1914), No. 4, pp. 363-374.
(2) Harris, F. S. Effects of variations in moisture content on certain properties of a soil and on the growth of wheat. New York Cornell Sta. Bul. 352 (1914).
(3) Bouyoucos, G. A. A new classification of the soil moisture. Soil Sci., 11 (1921), No. 1, pp. 33-47.
(4) Fisher, E. A. Remarks and observations on imbibitional soil moisture. Jour. Agr. Sci. [England], 14 (1924), No. 2, pp. 204-220.
(5) Wintermeyer, A. M. Percentage of water freezable in soils. U. S. Dept. Agr., Public Roads, 5 (1925), No. 12, pp. 5-8.
(6) McCool, M. M., and Weidemann, A. W.—Some moisture relationships of soils. Soil Sci., 20 (1925), No. 3, pp. 243-247.
(7) Bouyoucos, G. The amount of unfree water in soils at different moisture contents. Soil Sci., 11 (1921), No. 4, pp. 255-259.
(8) Wilsdon, B. H. Studies in soil moisture. India Dept. Agr. Mem., Chem. Ser., 6 (1921), No. 3, pp. 155-186.
(9) Lobanov, N. V.—The minimum soil moisture available to plant roots. Nauch. Agron. Zhur. (Jour. Landw. Wiss.), 2 (1925), No. 4, pp. 243-256.
(10) Bouyoucos, G. Measurement of the inactive, or unfree, moisture in the soil by means of the dilatometer method. U. S. Dept. Agr. Jour. Agr. Research, 8 (1917), No. 6, pp. 195-217.

(11) Alway, F. J. Studies on the relation of the nonavailable water of the soil to the hygroscopic coefficient. Nebraska Sta. Research Bul. 3 (1913).

(12) Thomas, M. D. Aqueous vapor pressure of soils.—II, studies in dry soils. Soil Sci., 17 (1924), No. 1, pp. 1-18.

(13) Gardner, W. and Israelsen, O. W. Utah Sta. Bul. 198 (1926), pp. 51-56.

(14) Alway, F. J., Kline, M. A., and McDole, G. R. Some notes on the direct determination of the hygroscopic coefficient. U. S. Dept. Agr. Jour. Agr. Research, 11 (1917), No. 4, pp. 147-166.

(15) Blanck, E. The influence of lime on the movement of water in soils. Landw. Jahrb., 38 (1909), No. 5-6, pp. 715-758; abs. in Chem. Abs., 4 (1910), No. 1, pp. 73, 74.

(16) Patten, H. E. and Gallagher, F. E. Absorption of vapors and gases by soils. U. S. Dept. Agr. Bur. Soils Bul. 51.

(17) Petit, A. Observations relative to the influence of pulverization and settling of soil on its humidity. Ann. Sci. Agron. Franc. et Etrangere, 39 (1922), No. 3, pp. 170-176.

(18) Oden, S. Note on the hygroscopicity of clay and the quantity of water adsorbed per surface unit. Faraday Soc. Trans., 17 (1922), No. 2, pp. 244-248.

(19) Widtsoe, J. A., and McLaughlin, W. W. The movement of water in irrigated soils. Utah Sta. Bul. 115 (1912).

(20) Mendes, C. T. Hygroscopicity of soil. Escola Agr. "Luiz de Queiroz," Piracicaba, Brazil, Bol. 6 (1920).

(21) Sen, J. N., and Amin, B. M. Absorption of moisture by soils. Mem. Dept. Agr. India., Chem. Ser., 8 (1926), No. 12.

(22) Novak, W. Does a relation exist between hygroscopicity and mechanical analysis of soil? Landw. Jahrb., 50 (1917), No. 3, pp. 445-453.

(23) Puri, A. N., Crowther, E. M., and Keen, B. A. The relation between the vapor pressure and water content of soils. Jour. Agr. Sci. [England], 15 (1925), No. 1, pp. 68-88.

(24) Bouyoucos, G. J. Relationship between the unfree water and the heat of wetting of soils and its significance. Michigan Sta. Tech. Bul. 42 (1918).

(25) Bouyoucos, G. J. Relation between heat of wetting, moisture equivalent, and unfree water. Soil Sci., 14 (1922), No. 6, pp. 431-434.

(26) Mason, T. G. The physiological humidity of the soil and its direct determination. West Indian Bul. 19 (1922), No. 2, pp. 137-154.

(27) Keen, B. A. The system soil—soil moisture. Faraday Soc. Trans., 17 (1922), No. 2, pp. 228-243.

(28) Bouyoucos, G. J. Effect of temperature on some of the most important physical processes in soils. Michigan Sta. Tech. Bul. 22 (1915).

(29) Israelsen, O. W. Studies on capacities of soils for irrigation water and on a new method of determining volume weight. Jour. Agr. Research [U. S.], 13 (1918), No. 1, pp. 1-36.

(30) Harding, S. T. Relation of the moisture equivalent of soils to the moisture properties under field conditions of irrigation. Soil Sci., 8 (1919), No. 4, pp. 303-312.

(31) Alway, F. J., and Russel, J. C. Use of the moisture equivalent for the indirect determination of the hygroscopic coefficient. U. S. Dept. Agr. Jour. Agr. Research, 6 (1916), No. 22, pp. 833-846.

(32) Briggs, L. J., and McLane, J. W. The moisture equivalent of soils. U. S. Dept. Agr. Bur. Soils Bul. 45.

(33) Shaw, C. F. California Sta. Rpt. 1925, pp. 65, 66.

(34) Shaw, C. F. The normal moisture capacity of soils. Soil Sci., 23 (1927), No. 4, pp. 303-317.

(35) Israelsen, O. W., and West, F. L. Water holding capacity of irrigated soils. Utah Sta. Bul. 183 (1922).

(36) Powers, W. L. Field moisture capacity and wilting point of soils. Soil Sci., 14 (1922), No. 2, pp. 159-165.

(37) Juritz, C. F. Notes on soil moisture. Agr. Jour. Union South Africa, 2 (1911), No. 6, pp. 739-758.

(38) Puchner, H. Investigations on the water carrying power of the soil. Internatl. Mitt. Bodenk., 1 (1911), No. 2, pp. 99-137.

(39) Leather, J. W. The loss of water from soil during dry weather. Mem. Dept. Agr. India, Chem. Ser., 1 (1908), No. 6, pp. 75-116.

(40) Alway, F. J. and McDole, G. R. Relation of movement of water in a soil to its hygroscopicity and initial moistness. U. S. Dept. Agr. Jour. Agr. Research, 10 (1917), No. 8, pp. 391-428.

(41) Alway, F. J., and McDole, G. R. Relation of the water retaining capacity of a soil to its hygroscopic coefficient. U. S. Dept. Agr. Jour. Agr. Research, 9 (1917), No. 2, pp. 27-71.

(42) Middleton, H. E. The moisture equivalent in relation to the mechanical analysis of soils. Soil Sci., 9 (1920), No. 2, pp. 159-167.

(43) Monroe, B. F. California Sta. Rpt. 1921, pp. 19, 20, 21, 22, 23.

(44) Bradfield, R. et al. Missouri Sta. Bul. 236 (1926), pp. 23, 77-84.

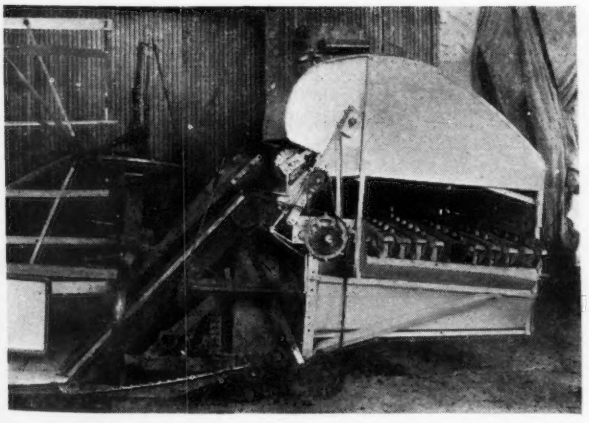
(45) Blanck, E. The action of commercial fertilizers on percolation of water in soils. Landw. Jahrb., 38 (1909), No. 5-6, pp. 863-869.

Threshing Attachment for Grain Binders

By J. C. Wooley[1]

DURING the past five years, the department of agricultural engineering at the University of Missouri has been working on the problem of harvesting soy beans. The threshing attachment for grain binders has been developed to fill this need. Five different models have been built in the process of development. The conditions we have attempted to meet are as follows: First, light weight so as not to overload the binder frame; second, small power requirement so that power could be secured from the drivewheel of the binder under ordinary conditions; third, use on any binder so that the farmer could use the machine which he now has; fourth, complete removal of beans from pods; and fifth, not more than thirty per cent of pods to be collected with the beans.

[1]Professor of Agricultural Engineering, University of Missouri. Mem. A.S.A.E.



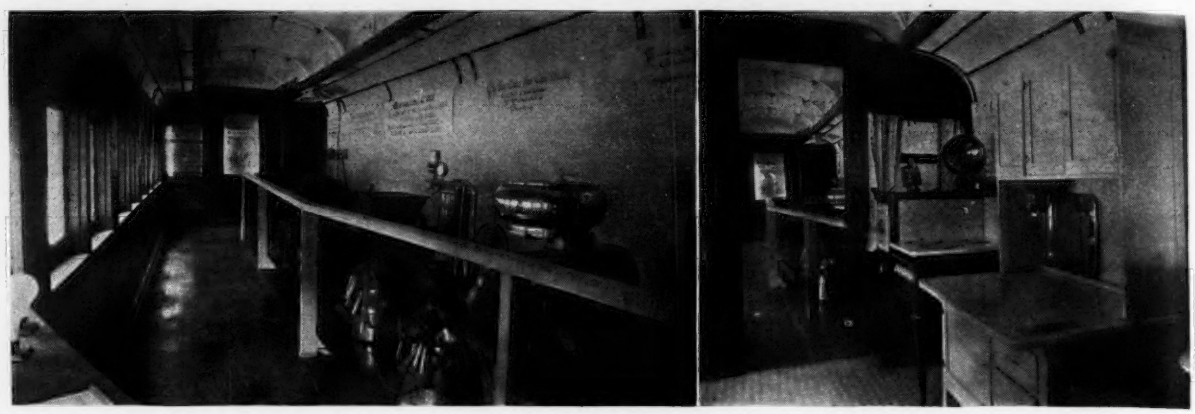
Rear view of Missouri soy bean threshing attachment

The machine shown in the accompanying picture is about 150 pounds heavier than the binder head which was removed, but most of the weight is concentrated near the drivewheel so that no undue strains are produced.

There are but three main working parts: the cylinder, the straw rack and the feed rollers. During the past fall it was necessary to use a power take-off to drive the binder and attachment due to the excessive amount of rain. The machine is made standard for the different binders, the only change required is in the connecting castings and drive sprocket. When beans are ripe and dry, the threshing has been very satisfactory. A change in cylinder speed has been provided, but under the conditions mentioned, 400 to 450 r.p.m. is rapid enough to break open all of the pods and still not crack any of the beans.

For bulk storage, the thirty per cent pods mixed with the beans serve a good purpose in preventing heating. These pods take up excess moisture and allow some ventilation. A fanning mill can be used to clean the seed during the winter months.

The collecting bin on the attachment is placed directly under the straw rack and is built large enough to hold six bushels. This will enable the farmer to drive from forty to eighty rods before sacking or shoveling the beans into a wagon. A wagon placed at the end of the field will enable him to handle the threshed beans without much difficulty.



Interior of the electrical exhibit car fitted out by the Agricultural Experiment Station, Purdue University, with all kinds of farm and home electrical labor-saving equipment. In cooperation with the Indiana electric light and power companies it was run over practically all the electric lines of the state for fifty-one days

Indiana's Farm Electric Car

By Truman E. Hienton[1]

INDIANA now has slightly over five thousand farmers who secure light and power service from rural electric lines.

In order that these and other interested farmers might learn the results of the experimental work on rural electrification in Indiana, an exhibit covering about 1200 square feet of floor space was erected in the Purdue building at the 1926 Indiana State Fair. This exhibit was viewed by approximately one hundred sixty-five thousand people of which sixty per cent were farmers and their families. The attendance from several sections of the state where rural lines are in use was rather small due to their distance from Indianapolis. In order that such communities might know the results of the experimental work, a traveling exhibit was planned. The Indiana Electric Light Association assisted in planning and conducting this project.

The loan of an interurban car was secured and funds provided for its operation through the Association. The car was equipped by members of the Agricultural Engineering Division of the Purdue Agricultural Experiment Station. It was handled free of charge by the traction companies and traveled over the major portion of the interurban system of the state.

The car was exhibited fifty-one days in forty-eight counties of the state at one hundred and eighty-two towns and villages to slightly over 27,000 persons. The attendance, while small compared to that at the state fair, was made up of people directly interested in the equipment shown. In a great many cases muddy roads made it necessary for farmers to come on horseback or with a team and wagon, and only those directly interested could be expected to visit it under such conditions. Six thousand copies of a special folder and four thousand copies of a larger bulletin on the uses of electricity on the farm were distributed.

Exhibits in the car were divided into two sections. The front end of the car or smoker was equipped as a kitchen and contained the following electrical equipment: washer, iron, ironer, vacuum cleaner, toaster, percolator, waffle iron, cooker, table stove, fan, refrigerator, water heater and range. The rear end of the car contained an automatic water pump; two milkers, one portable and the other stationary; a motor-driven cream separator; a 5-hp. portable motor, two ¼-hp. portable motors; a small electric incubator; a miniature lighting system for use in poultry houses; an electric soldering iron; and an exhibit showing progress in the development of lamps.

A 220-volt, three-phase alternating-current generator was installed in the front end of the car and driven by a 6-hp. kerosene engine. The generator provided sufficient energy so that the equipment in the car might be demonstrated. However, at a large number of the stops an electric line was dropped into the car and the generator was not used.

The equipment for the farm home was demonstrated by a representative of the home economics extension division of Purdue University. Equipment for the farm was demonstrated by a member of the agricultural engineering department.

It is expected that the most immediate result of this exhibit will be to interest farmers who have rural line service or individual plants in using electrical equipment which is adapted to the needs of their farms. Another result which is not so immediately apparent is the awakening of a desire among farmers to secure rural electric service and with it the equipment proven practical in the Indiana rural electrification investigations.

[1]Project leader in rural electrification, Agricultural Experiment Station, Purdue University. Assoc. Mem. A.S.A.E.

Stationary Spray Plants Increasing

By L. J. SMITH[2]

MANY additional electric spray plants are being installed in the Wenatchee Valley of Washington this spring. Two crews of the Puget Sound Power & Light Company have been working steadily for over two months extending the company's lines to ranches desiring electric power for spraying and irrigation service.

Eighty new electrically driven spray plants have been installed this spring, which will spray 950 acres of orchard. There are already 360 electrically operated stationary spray outfits in the Wenatchee area which take care of a little over 4,000 acres of orchard. The stationary spray plant is considered the standard apparatus for orchard work in the Wenatchee country.

Washington Farmers Electrify

THAT rural electrification is making good headway in the state of Washington is shown by statistics recently gathered by the Washington Committee on the Relation of Electricity to Agriculture. L. J. Smith, of the Washington State College, secretary of the Committee, says that the figures collected show that 55 per cent of the farms of the state had central station current at the close of 1926.

More than 38,000 farm customers comprise the 55 per cent. Of this number, nearly six thousand are new customers taken in in 1926.

The figures do not include the number of farmers that are receiving current from central stations through small cooperative associations, and those who have their own individual lighting units.

[2]Professor of agricultural engineering, State College of Washington.

Rural Electrification as an Opportunity for the Agricultural Engineer

By E. A. White[1]

FROM the standpoint of the agricultural engineer electric service for the farm is entering a new phase of development. The work of the past three years has been largely of a preliminary nature. We have been exploring for possibilities and problems, getting acquainted with the field. The time has now arrived when known information can be worked into extension programs and research projects organized to delve further into the great unknown.

There can be no doubt that the farmer is interested in electric service. According to information recently collected by the Rural Electric Service Committee of the National Electric Light Association, there has been an increase of eighty per cent in the farmers receiving service from transmission lines during the past three years. This means that in round numbers 300,000 farmers are connected today. Undoubtedly there are many farmers using individual lighting plants. Men who are giving close study to rural electrification look for one million farms to be securing service from transmission lines in the near future, and for a further increase in the use of the individual plant. In the light of these developments, past and prospective, it is highly desirable that all possible information be made available to farmers. In other words, extension work is needed.

There are several ways of organizing an extension program which will differ with conditions and personnel. It would seem that a sound extension program would be designed with a view to making information regarding rural electrification available rather than urging farmers to electrify. There is a vast difference between making information available and aggressively urging a development. The latter is represented by the corn borer campaign. Such a development is not desirable in rural electrification.

As most of us learn both faster and better from what we see than from what we hear or from what we read, especially when things mechanical are concerned, it appears logical that properly organized demonstrations will form the backbone of an extension program on rural electrification. This does not exclude the spoken message or the printed word, but these will be supplementary rather than primary.

There can be a program worked out which will include the installation, in selected districts, of proper wiring systems and every proved use of electricity on the farm. This can be supplemented as desired, but certainly it would be sound to place in the county agent's hands a handbook on rural electrification. In fact this extension work has already started. The agricultural extension department of the University of California has a lighting exhibit which can be transported on a truck. This work has been well received. Under the direction of the Wisconsin Committee on the Relation of Electricity to Agriculture a number of electro test farms have been established with gratifying results.

In Indiana considerable interest was aroused by a rural electrification demonstration car operated over the interurban lines of the state under the general supervision of Purdue University. Twenty-five thousand people visited this car during eight weeks.

Perhaps the most outstanding extension program has been started in Pennsylvania where the state council of agricultural organizations and the Pennsylvania Electric Association have cooperated in organizing the Pennsylvania Joint Committee on Rural Electrification for the express purpose of promoting the extension of electric service to the farm. In this work the extension service of Pennsylvania State College is cooperating.

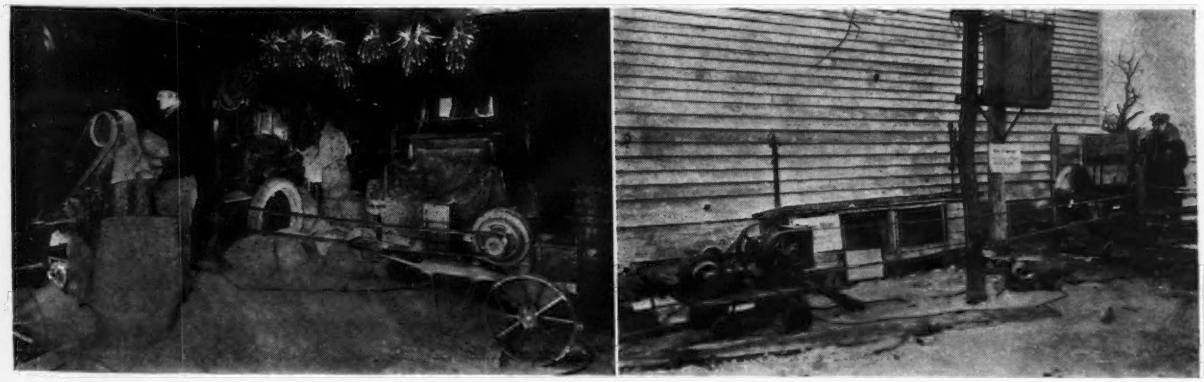
From a national standpoint the farmer knows relatively little about electric service. Its installation is a primary financial undertaking. This is an ideal situation for extension work to render agriculture a valuable service.

Conditions now offer an unusual opportunity for the agricultural engineer to organize a national correlated research program on rural electrification. Some of the problems are sectional; others are national. These need to be classified and listed for definite attention. To secure results from such a program the classifying should be done by men acquainted with the details, that is, men who have studied the situation. There are a number of individual research projects such as refrigeration, brooding, grain drying, hay drying, feed grinding and overhead irrigation which call for attention, but perhaps the biggest field for research work relates to an engineering reorganization of agricultural practices in order to take full advantage of known possibilities. Electric service means a monthly bill for current with carrying charges for equipment. It carries new possibilities.

Organizing a productive enterprise such as agriculture to meet the cost and take full advantage of conditions is a major undertaking. Perhaps we need a different type of farm unit than is common today. Perhaps it will be ultimate economy in view of modern transportation facilities to develop farm centers. There is a sociological or humanitarian aspect to the problem which the engineer may well study.

Take dairying as the most outstanding example. Cows require attention twice a day, three hundred and sixty-five days a year. This may be efficiency in the use of man labor, but from the engineer's standpoint it is another form of slavery. An American citizen ought not to be tied to a job every day in the year. He is entitled to at least one day

[1]Director, Committee on the Relation of Electricity to Agriculture. Charter, A.S.A.E.



(Left) General Electric 5-horsepower portable farm motor driving a feed grinder on a farm at Alplaus, New York. (Right) A General Electric farm chore motor belted to a buzz saw. The motor may be started or stopped by the operator from his position at the saw by pressing a button

per week for recreation and enjoyment. A new idea perhaps for agriculture, but certainly not for the American worker. Power introduced into agriculture should bring needed reforms. Perhaps the most satisfactory way to handle the production of dairy products is to have a six-man unit with seven men employed. Then each man can have one day per week of leisure. A dream? Not for the engineer!

Agriculture cannot remain aloof from this general trend. The agricultural engineer has much to think about. Among other things it is his opportunity to use rural electrification as an entering wedge to a research program which can remake our agricultural structure in twenty-five years.

Electric Current Consumption On Seven New Hampshire Farms*

SEVEN farms in New Hampshire, representing dairy, poultry, fruit and general farms, were selected in the spring of 1925 and equipped with appliances to determine what limits in quantity of electricity can be economically used and to secure data on the efficiency of the different appliances. The farms were chosen as typical of substantial and successful enterprises operated with modern, well-balanced methods.

Sixty major and forty minor pieces of electrical equipment are now in use on these farms covering thirty-six distinct operations and metered in such a way that detailed records can be secured each month for nearly every appliance.

Current consumption on the seven farms averaged 1683 kilowatt-hours for the year 1925 and increased to 4253 kilowatt-hours in 1926.

Heating equipment, such as refrigeration, ranges, ironers, water heaters, etc., produced the greatest effect on the total consumption and developed a peak load in midsummer.

Total consumption for the year 1926 was distributed as follows: winter, 23 per cent; spring, 16 per cent; summer, 32 per cent; and fall, 28 per cent.

Total consumption by farms for 1926 ranged from 432 kilowatt-hours for the fruit farm to 7694 kilowatt-hours for one of the dairy farms.

The records are still too limited to draw many detailed conclusions, and further research, particularly with farmstead appliances, is desirable.

House lights showed an average monthly consumption of 34.6 kilowatt-hours, ranging from 15.2 to 63.3.

Water pumps showed an average monthly consumption of 23.7 kilowatt-hours, ranging from 3.7 to 39.

Kitchen ranges showed an average monthly consumption of 167 kilowatt-hours, ranging from 26 to 282. Combination ranges with wood and coal and straight electric ranges are being used.

House refrigerators used an average of 35.3 kilowatt-hours per month, ranging from 23 to 39.5.

Hot water heaters used an average of 182 kilowatt-hours per month, ranging from 15.2 to 548. They have given a high degree of service, but their cost of operation has been high.

Washing machines used an average of 2.6 kilowatt-hours per month.

Flatirons used an average of 7.3 kilowatt-hours per month, and ironing machines 12.7.

Barn lights used an average of 7.9 kilowatt-hours per month, ranging from 4.3 to 13.9.

Milking machines used an average of 91.5 kilowatt-hours per month, ranging from 56.5 to 134.

Dairy cooling rooms showed an average monthly consumption of 119 kilowatt-hours, ranging from 96.5 to 148.

*A summary of Bulletin No. 228, entitled "Electricity on New England Farms," by W. T. Ackerman, issued by the New Hampshire Agricultural Experiment Station, March, 1927.

Farms Receiving Electric Service

THE 1926-27 report of the Rural Electric Service Committee of the National Electric Light Association presents data on the number of farms which are receiving electric service by states, which is of particular interest as indicating the rate of development in the application of electricity to agriculture. The figures in the table below show the total number of farmers which in 1926 were receiving central station electric service:

Alabama	2,000	North Carolina	2,467
California	62,000	Oklahoma	330
Colorado	1,800	Florida	1,015
New York	35,600	Georgia	510
Idaho	6,900	Pennsylvania	19,369
Illinois	7,260	South Carolina	1,250
Indiana	5,100	Tennessee	1,225
Iowa	13,600	Utah	8,050
Kentucky	1,950	Washington	20,000
Michigan	6,800	Wisconsin	11,000
Missouri	3,766	Wyoming	325
Montana	700		
Nebraska	2,500	Total (27 states)	227,442
New Jersey	3,950	Same states, 1923	121,854
New Mexico	375		
Oregon	7,600	Increase, 3 years	105,188=86.6%

From Oxen to Tractor

This picture shows an Agricultural Engineering float used in the Hobo Day parade at South Dakota State College on October 30. It was one of eighty-seven floats in the parade. The man holding the plow handle does not present a special make-up for the occasion. He is Henry Stearns, an old pioneer in the Northwest country, who has broken many acres of virgin sod with oxen. They were unable to find a team of oxen for the occasion and finally had to break one. Members of the agricultural engineering staff at the college took turns with this team and broke the animals in a single week, getting them through the city streets under exciting conditions without a "bobble." Photo from R. L. Patty

Theoretical Considerations of Thermal Characteristics of Dairy Equipment Sterilizers

By A. W. Farrall[1]

FOREWORD

Sterilization of utensils used in the handling of milk products is today recognized as an absolute necessity if the best quality of milk is to be produced and delivered to the consumer. All surfaces cans and containers, as well as milking machines and coolers, tend to collect pathological bacteria which, if allowed to come in contact with milk, will contaminate it. It has been found that most of these bacteria can be killed or rendered harmless by heating to a temperature of 210 deg. F. and steaming for 20 minutes. It has also been found that utensils heated in hot air to a temperature of 230 deg. F. for 30 minutes are rendered practically sterile.

Numerous types of apparatus have been developed for performing this operation. The accompanying illustration shows a common type of sterilizer of sufficient capacity to handle four ten-gallon cans at a time. This particular apparatus consists of an enclosed tank in which the utensils are placed along with a small amount of water and an oil burner which is placed underneath the sterilizer box for heating the water and generating steam. In order for an apparatus of this type to be practical it must be efficient as regards time and energy consumed, and be able to produce desirable bacterial reduction on equipment sterilized. The small tank type sterilizer is quite efficient and its cost of operation should not be more than 4 to 10 cents per batch sterilized, for a four-can size. Larger steam boiler outfits will cost more to operate and are out of question for the small dairyman. New types of electrically heated dairy sterilizers have appeared upon the market and seem to offer certain advantages.

In 1917, Dr. C. L. Roadhouse, of the dairy industry division of the University of California, published Bulletin No. 179, entitled "Factors of Importance in Producing Milk of Low Bacterial Count," in which he emphasized the importance of sterilization and showed plans for constructing a simple sterilizer. In 1923 the dairy industry division undertook a study of the oil-heated sterilizer and the steam boiler outfit, and then in 1925, in cooperation with the California Committee on the Relation of Electricity to Agriculture, continued the work with a study of the electrically heated sterilizer.

Mention should be made of the assistance given by Dr. C. L. Roadhouse and Dr. C. S. Mudge, dairy bacteriologist, also of the cooperation of Prof. B. D. Moses, director of the California Committee on the Relation of Electricity to Agriculture, and T. A. Wood, field engineer of the Committee.

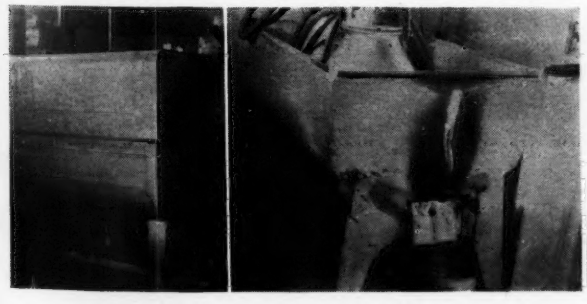
Some of the results of the investigations will be published in AGRICULTURAL ENGINEERING in a series of papers (the first of which appears in this issue) as follows:

1. Theoretical Consideration of Thermal Characteristics of Dairy Equipment Sterilizers
2. Study of Operating Characteristics of Oil Heated Steam Type Dairy Equipment Sterilizers
3. Study of Operating Characteristics of Electrically Heated Steam Type Dairy Equipment Sterilizers
4. Study of Operating Characteristics of Electrically Heated Dry Hot Air Dairy Equipment Sterilizers

ALL dairy equipment to be sterilized should be thoroughly washed and all organic matter removed from the surface of the metal; otherwise there is danger of solids being burned on, making an impervious deposit.

For proper sterilizing of utensils it is only necessary to heat them to the required temperature for the required length of time; it is also desirable that the utensils be left dry after sterilizing in order to prevent rapid growth of bacteria and deterioration of equipment. The problem then is of a mechanical and thermal nature, consisting of the design of a piece of apparatus which will heat equipment uniformly, quickly, and to the proper temperature with a minimum amount of heat energy.

[1]Junior Agricultural Engineer, University of California. Assoc. Mem. A.S.A.E.



Two views of a common type of dairy sterilizer

The heat required for sterilizing may be divided into the following parts.

1. **The Heat Required for Warming the Sterilizer Proper.** This is found by the general formula, B.t.u. $= W \times c \times (t_1 - t_2)$. W is the weight of the sterilizer, c is the specific heat of the metal, t_2 is the original temperature, and t_1 the final temperature.

This is an important consideration with some types of sterilizers in which a large mass of metal or concrete must be heated. Oftentimes more heat will be required to raise the temperature of the sterilizer than that of the utensils within, which are to be sterilized. The small four-can size sterilizer may weigh from 85 to 130 pounds, and the temperature rise may be from 60 to 200 degrees Fahrenheit. With a 100-pound sterilizer the heat absorbed would be

$$100 \times 0.113 \ (200 - 60) = 1582 \text{ B.t.u.}$$

This portion of heat requirement of a sterilizer may be kept at a minimum by building the parts as compact as possible and as light as consistent with structural strength and durability.

2. **The Heat Required to Warm the Convecting Medium to the Maximum Temperature Attained.** The three common heat convecting mediums are air, water and steam. In the case air is used this amounts merely to the heat absorbing capacity of the air which would be given by the general formula, B.t.u. $= W \times c \times (t_1 - t_2)$, the same as previously mentioned. This is obviously a very small quantity of heat as the weight of air contained in a small sterilizer is negligible and, furthermore, the specific heat of air at constant volume is only 0.2375.

In case water is used for the convecting medium the same general formula holds as before, except that since the weight of water is considerable and the specific heat is high the (unuseful) heat absorbed is quite large, especially if the apparatus requires a considerable volume of water.

In case steam is used for the convecting medium and is generated from water held within the sterilizer or in a boiler, the (unuseful) heat will be that absorbed by the water in raising it to the temperature of the boiling point, plus the latent heat of the steam required to fill the container and care for leaks. The average four-can capacity sterilizer which generates steam from the small amount of water in the bottom uses from 10 to 50 pounds of water. The steam lost by evaporation and leakage to the atmosphere amounts to about 2 to 3 pounds for each sterilization depending upon the degree of insulation of the sterilizer, the size of the heating element, time of heating, etc. The loss in heating 50 pounds of water from 70 to 212 deg. F. is $50 \times 1 \times (212 - 70)$, or 8,100 B.t.u.; the loss in heating 10 pounds of water is 1,620 B.t.u.; the loss in evaporating 2 pounds of water would be 2×970.4, or 1940.8 B.t.u. The disadvantage of using a boiler or sterilizer of large water capacity is therefore evident.

3. **The Heat Required to Overcome Heat Radiation and Conduction From the Surface of the Sterilizer.** This becomes important in the tank type sterilizer since such large areas are exposed to the atmosphere. The radiation and conduction will vary according to the nature of the atmosphere, the type of surface, and the air currents.

The following laws state the facts governing the losses from this source:

(a) **Radiation.** Radiation loss follows the law of Stefan Boltzman, in which it is stated that the energy radiated is proportional to the fourth power of the abso-

lute temperature, or $E = K (t^4 - t^4_o)$, where t_o is the temperature of cold object, t the temperature of the warm object, K is a constant, and E is the energy radiated.

The above law may also be written

$Q = K F t (T \div 100)^4$, in which Q is the heat emitted in B.t.u.;

K is a constant of known value, depending upon the material of the radiating body (for dull zinc this value is 0.034 [Kent]); F is the area of the radiating surface in square feet, t is the time in hours, and T is the absolute temperature in degrees F.

(b) **Conduction.** Conduction loss is very high through a single thin metal wall, and this can only be cut down by means of insulation. Insulation reduces the conductivity of the wall, thereby lowering the outer temperature and decreasing the loss by radiation and convection.

(c) **Convection.** Losses due to convection currents are large and the velocity of the air currents plays an importana part, since, according to Langmuier, still air convection losses should be multiplied by the formula, $(V + 18) \div 18$, where V is the velocity of the air in feet per minute. The importance of setting the sterilizer out of drafts is emphasized.

4. **The Heat Required to Raise the Temperature of the Equipment Which is Being Sterilized.** The same general formula, B.t.u. $= W \times c \times (t_1 - t_2)$, gives the amount of heat absorbed.

The specific heat of milk-can metal is approximately 0.113; the weight of a 10-gallon can is 24 pounds, and the temperature rise would be from approximately 60 to 230 deg. F. or 190 deg. F. Therefore B.t.u. absorbed $= 24 \times .113 \times 190 = 513.8$.

In order for the utensils within the sterilizer to become heated some convecting medium must be used. This is usually either hot air, hot water, or steam. If hot air or hot water is used, strong convection currents must be set up within the sterilizer in order to properly transfer the heat. This requires either a considerable temperature difference in various parts of the sterilizer, notably the top and bottom, or else some means of forced circulation.

If steam is used, there will be a more uniform temperature within the sterilizer under normal conditions since the steam condenses at a certain temperature and gives up its heat, maintaining the temperature of the boiling point for the particular pressure.

There is a certain amount of heat transfer within the sterilizer, between the utensils themselves, and also between the utensils and metal parts of the sterilizer. The laws of radiation, convection and conduction apply in each instance just as much as in the case of losses from the external surface of the sterilizer. There is a tendency for all parts to become of the same temperature, although this ideal is seldom or never reached in practical application, as differences of 10 deg. F. have been found in steam-heated sterilizers and as high as 90 deg. F. in the hot air type sterilizers. In all types of apparatus provision should be made for efficient circulation of the convecting medium between and around the utensils to be sterilized.

Wood Utilization Studies

DEFINITE and substantial results have been obtained by the National Committee on Wood Utilization on the several short time projects on which it has concentrated its attention since its inception in April, 1926.

As the work of this committee has developed it has become apparent that basic information in regard to many problems has been lacking. It therefore seems necessary, as a basis for further educational activities, that the committee develop a series of bulletins containing such information as is needed.

A bulletin on the utilization of products and the manufacture and use of wood flour has been prepared and will soon be in print.

A comprehensive treatise on the distillation of hard wood and soft wood is now in its final stage of development and will soon be submitted to the wood chemical subcommittee for approval.

The committee is now gathering material for four bulletins on the seasoning and handling of lumber.

The construction subcommittee has prepared a report on the marketing of short-length lumber, with particular reference to building and construction. The subcommittee on end-matching of softwood lumber has finished its report, which represents largely a follow-up of the short-length bulletin. It will demonstrate that by end-matching short-length stock will find a wider application.

Special study has been made in regard to sawmill machinery and equipment, and a subcommittee has been organized for the purpose of studying gang sawing of logs according to the North European system. Other studies are being undertaken which entail the resawing of lumber by using conical circular saws of very small kerf and giving the lumber a smooth finish which eliminates the necessity of dressing the stock.

The committee has organized an association of small-dimension stock producers, to promote the use of small-dimension stock.

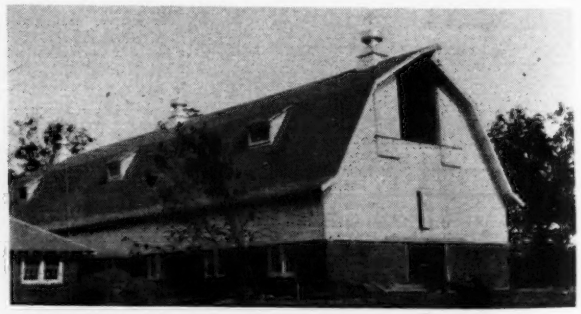
A project has been started whereby one of the committee members who is doing a wholesale and retail business in the Middle West has been put in touch with a well-known wood preserving plant and the two are cooperating in building up the trade in preserving wood in a restricted area.

Separate groups representing fiber and wood-container manufacturers have just started their program. Two exhibits have been held to call the attention of the public to scientific container construction.

A special project committee has been established to take an inventory by states of nonutilized wood. Virginia is the first state organized to carry on this work. It is hoped that definite information will be obtained as to the quantity and character of available nonutilized woods.

The common purpose of the committee members is to give the necessary impetus to commercial reforestation through increase of utilization of the tree and its products.

The picture shows the new concrete, tile and frame dairy and horse barn, recently erected at one of the branches of the University of Arkansas at a cost of approximately $15,000. The barn is 36 by 122 feet. The department of agricultural engineering at that institution, of which Deane G. Carter is the head, believes that in order to do effective teaching it is necessary to keep in touch with the practical side of the subjects they teach.



An Inexpensive Drawbar Dynamometer

By E. C. Sauve[1]

IN THE spring of 1925 it was my duty and privilege to design and build an oil compression dynamometer. It was not until I had investigated quite thoroughly the dynamometer field that I began this work. The cost of a suitable recording drawbar dynamometer produced in commercial quantities was beyond our reach. The spring type of dynamometer, while inexpensive, was not suitable for our work, inasmuch as it was not a recording instrument and was constantly getting out of adjustment. Consequently I began to analyze this dynamometer problem and concluded that the following were the essential requirements:

1. It must be of the recording type insofar as draft is concerned
2. It must be adapted to recording instruments now available on the market
3. It must be applicable to light as well as heavy loads
4. It must find application on a great variety of field machines
5. It must be close coupled
6. It must be inexpensive to construct

The dynamometer and recorder as shown in Fig. 1 represent, I believe, the fulfillment of these requisites.

Cylinder and Piston. The cylinder and piston, details as shown in Fig. 2, were designed to carry a safe load of 1500 pounds under compression. Tests in the field, under somewhat adverse conditions during the past two years, leave little to be desired in the way of any radical improvement. It works and produces a readable and satisfactory chart. Note the similarity of the first and third draft lines as well as the second and fourth as shown in Fig. 4. These represent adjacent furrows.

Lubrication oil of a medium or light grade is used in the cylinder. The pressure is transmitted from the load through the levers and piston to the oil in the cylinder. The oil under pressure connects through a small flexible tubing to the Bristol recorder. On examining the piston construction it will be noted that no rings are used. I found that none were necessary inasmuch as there was very little oil leakage with the rings removed. On examination of the drawings, showing the piston detail, it will be noted that there is a ball check valve held in place by a small coil spring. This valve is to permit the oil to return to the head end of the cylinder. This can readily be done by holding the cylinder in one hand and pulling the piston rod with the other, or in the field it can be done by prying the two apart with a wrench handle or other type of lever. The oil capacity of the cylinder is small, requiring less than a cupful to fill. It will be observed in Fig. 1 that there is a vent valve at the piston rod end of the cylinder. Normally, in operation, this vent valve should be open. It is closed only while the piston is being returned to its working position.

The total weight of the dynamometer including levers is about 20 pounds.

Levers. Two sets of levers were designed and built to permit of handling maximum loads of 1000 and 3000 pounds, respectively. It is only necessary to change the levers and the charts to adapt the dynamometer to the maximum loads anticipated.

Recorder. The recorder manufactured by the Bristol Company, Waterbury, Connecticut, is of the portable type and designed for pressures from zero to 300 pounds per square inch. A one-hour clock was installed. A special cylinder pen was purchased to prevent spattering of the ink when used in the field.

Tubing. The connection between the dynamometer and recorder is by means of a small copper tubing. While this tubing permits of some flexibility, it is not altogether satisfactory. At this writing an all metal flexible tubing has been ordered to replace the copper one. It is known as the "Titeflex" all metal tubing and is manufactured by the Titeflex Hose Company, Newark, New Jersey. It has an inside diameter of one-eighth inch and is guaranteed to withstand pressures in excess of 300 pounds per square inch.

Charts. Two sets of charts are required to accommodate the two sets of levers. One of the charts is known as No. 2198, graduated from zero to 30 which can be used to record loads within the range of zero to 3000 pounds, and the other chart is known as No. 2222, graduated from zero to 1000 pounds.

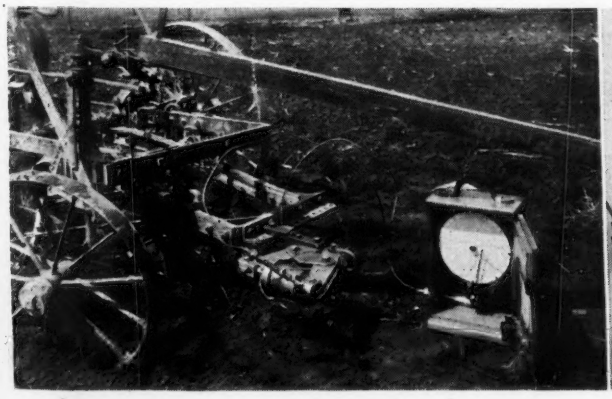
Operation. In the majority of field draft tests, it is possible and desirable to have the dynamometer installed on the implement or source of power in a horizontal manner as shown in Fig. 5.

Occasionally with tongued implements where there is plenty of clearance the dynamometer cylinder hangs or is in a vertical position. Special clevises can be made to adapt this dynamometer to practically any type of drawbar load.

Dynamometer Calibration. It is very necessary that this dynamometer as well as others be calibrated for accuracy. For this purpose I was permitted to use an Olsen Universal testing machine through the courtesy of the engineering department of Michigan State College. With the 3000-pound levers, the recorder load was 2700 pounds for an actual load of 3000 pounds. With the 1000-pound levers, the recorder load was 943 pounds for an actual load of 1000 pounds.

Calibration curves were prepared with small load increments which represented in all cases straight lines so that any recorder load could quickly be corrected for the actual load.

[1]Assistant professor of agricultural engineering, Michigan State College



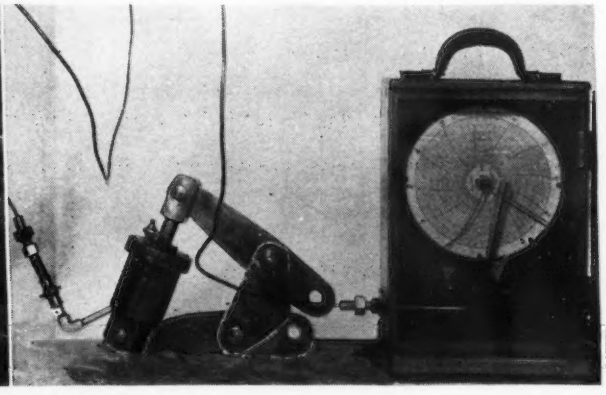


Fig. 1. (Right) Michigan oil-compression dynamometer with 3,000-pound levers, and recorder connected by copper tubing
Fig. 5. (Left) Dynamometer attached to a plow in a horizontal position

Average Draft. As previously mentioned Fig. 4 represents an actual test of a gang plow. The question arises, "How can one determine the mean height of this draft curve, so that it may be interpreted in pounds pull?" Let us take the problem as presented in the chart, Fig. 4.

Problem: Compute the average draft of the section represented by the chart between 40 minutes and 46½ minutes past the hour. Draw radii from 40 and 46½ to the center of the small circle. Since the areas of any two circles vary as the square of their radii, we have

$$A : A_1 :: r^2 : r_1^2 \quad \ldots\ldots (1)$$

Where A is the area of the sector of the small circle ABE, A_1 is the total area included within the draft curve ABCDE, r is the radius of the sector ABE, and r_1 is the radius of the average draft circle.

Thus $$\frac{A}{A_1} = \frac{r^2}{r_1^2} \quad \ldots\ldots (2)$$

or $$r_1 = \frac{\sqrt{A_1 \times r^2}}{A}$$

The average draft line $= r_1 - r$

$$= \frac{\sqrt{A_1 \times r^2}}{A} - r = r\frac{\sqrt{A_1}}{A} - r$$

But r = 1 1/16.

Therefore, the average draft line $= 1\ 1/16\ \frac{\sqrt{A_1}}{A} - 1\ 1/16$

Applying the values representing the measured areas as secured with a planimeter, we have $A_1 = 1.25$ square inches and A = 0.39 square inches.

Then average draft line $= 1\ 1/16\ \frac{\sqrt{1.25}}{.39} - 1\ 1/16$

= 0.837 inches.

But 2 27/64 inches on chart represent 3000 pounds.

Therefore, 1 inch — 3000 ÷ 2 27/64 = 1239 pounds.

1239 x .837 = 1037 pounds recorder load.

From the calibration curve 1037 pounds recorder load equals 1145 pounds actual load.

Where absolute accuracy is not required, the approximate average draft can be determined by an estimate secured from the chart, and then corrected from the calibration curve.

Horsepower Determination. Inasmuch as the majority of field tests are of short duration, it is an easy matter to measure off 200 or 300 feet and observe the time necessary to cover the distance. The average draft times the distance traveled per minute divided by thirty-three thousand (33,000) will give the horsepower developed.

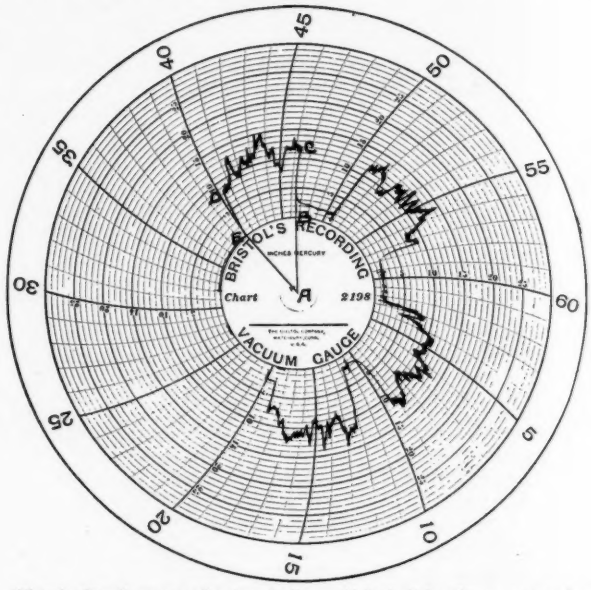


Fig. 4. Draft curve of a two-bottom, 14-inch John Deere gang plow

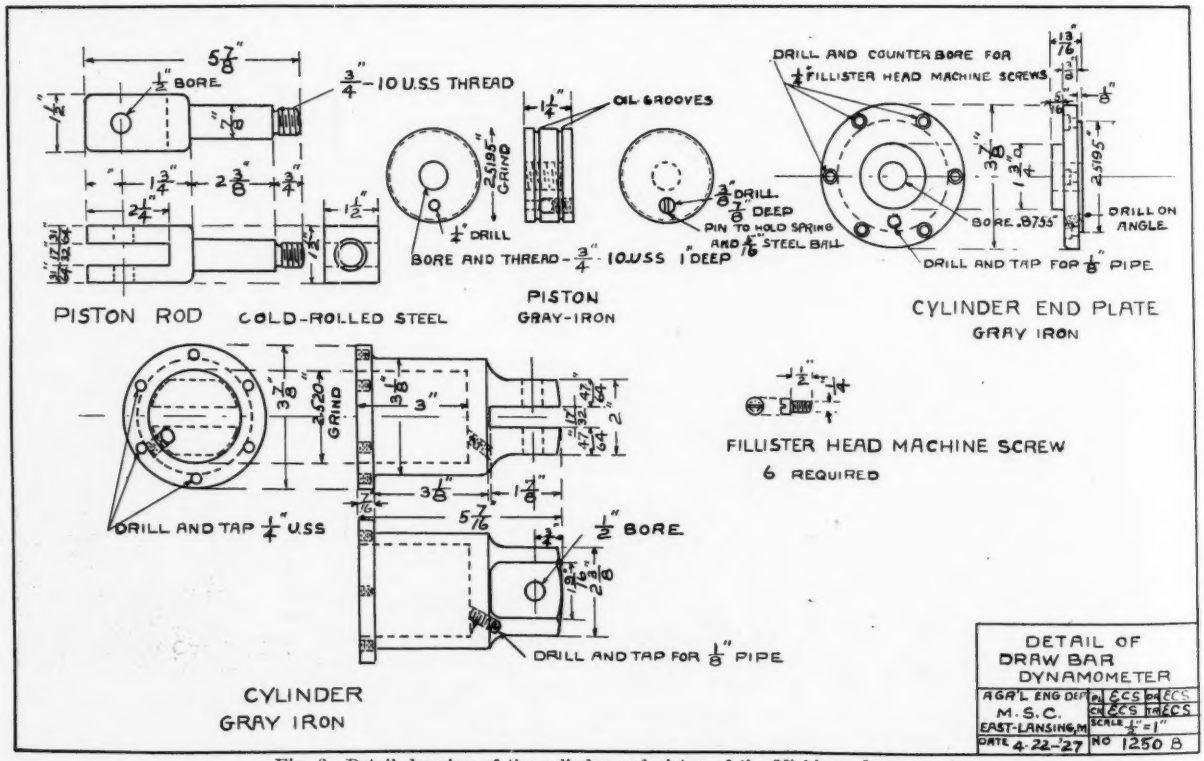


Fig. 2. Detail drawing of the cylinder and piston of the Michigan dynamometer

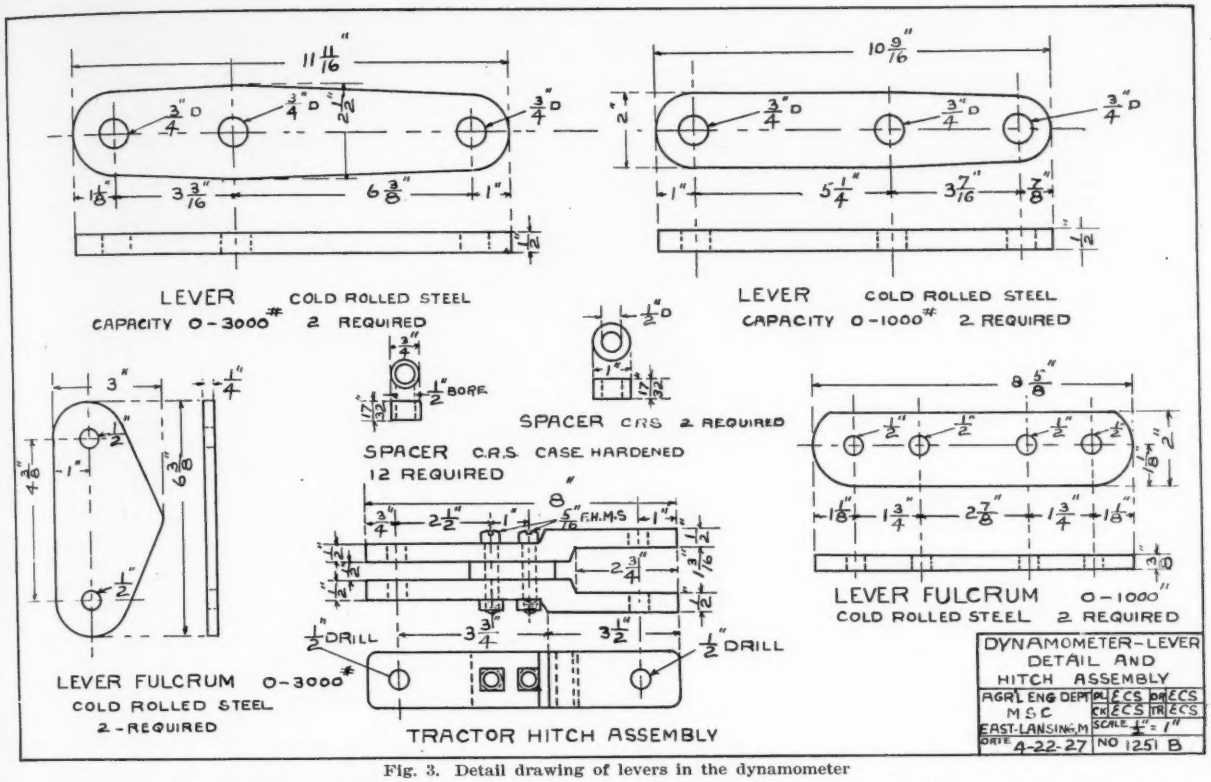


Fig. 3. Detail drawing of levers in the dynamometer

Cost of Construction. In the construction of this dynamometer, no effort was made to determine its cost. However, estimates have been secured from machines shops in which it is found that the value $65.00 should cover all costs of labor and material for the cylinder, piston, etc. and two sets of levers. The cost of the recorder would probably not exceed $60, making a total cost of $125 for the draft recording dynamometer.

Conclusions. No doubt, some may criticise this type of construction. I feel reasonably sure, however, that an expenditure of $125.00 to build this instrument will not be regretted, after it has been used in the field and its wide application discovered. In short tests a one-half-hour clock would perhaps be preferable to a one-hour clock, but this was not available at the time of purchase. In some localities a compression release valve might be desirable to protect the recorder against instantaneous loads. Reasonable care exercised in selecting the proper levers for the load should eliminate this danger.

A Thousand Hours Useful Life for Farm Equipment*

By Claude K. Shedd[1]

FARMERS during the past few years frequently have made complaint that farm implements are too high in price, although machinery manufacturers have made a convincing showing that implements sell cheaper than other commodities made of similar materials.

One of the first remedies proposed is to do without this high priced machinery. In order to do this one must farm a smaller acreage, hire more labor, or do a poorer job of farming. Any one of the three will prove more expensive or less profitable than using the high priced machinery. A second proposal is to use the old worn-out machinery instead of buying new. To follow this proposal also results in loss, not profit.

A third proposed method of combatting high expense for machinery is to take care of machinery so that it will last and give efficient service for a longer term of years, and here lies a real remedy for high machinery expense. Some farmers who are giving careful attention to the care and repair of their machinery are making it last and do good work for fully twice the number of years that such machinery usually lasts. This means that their annual expense for replacements is reduced by 50 per cent.

It must be admitted that farmers generally are extravagant in the rapid rate at which they wear out machinery. I know that a large amount of such machinery goes to the junk pile when it is not more than ten years old and it has been used only one or two weeks a year. This means only one hundred days of actual use.

Now compare this with the length of service which machinery gives in other industries. It is a matter of common knowledge that railroad locomotives last for 25 years or more. I do not know how many days per year a locomotive usually runs, but I suppose at least 200 days. This would make 5000 days in 25 years. Manufacturing industries also use many of their machines for 5000 days of service. Contrast this with the idea of many a farmer that when he has used a tractor for two years it is time to trade it in on a new one.

Competition is going to cause the survival of the fittest, and it looks to me as if the fittest is going to be the man who can get at least 1000 days of efficient service out of his machinery. In order to do this, it is necessary for a farmer to do just what other manufacturers do, that is, have a repair shop and give systematic attention to implement repairs.

Every implement on the farm should be given an overhauling once a year, and the best time to do this work is during the winter months.

*Abridgment of a radio talk from Station KSAC.

[1]Extension Agricultural Engineer, Kansas State Agricultural College. Mem. A.S.A.E.

The Drainage of Low Priced Agricultural Land*

By Lewis A. Jones[1]

THERE are two distinct types of farm drainage, namely, surface drainage and soil drainage. Surface drainage consists in promptly removing the water from the ground surface following a storm, so that evaporation may begin without the delay incident to the necessity of first removing a large quantity of standing water.

Soil drainage consists in promptly removing from the root zone of the soil all water that is harmful to plant growth. Such drainage is essential to obtain the best results and should be the ultimate aim in planning farm drainage. However, it is believed that many specialists, in advising farmers relative to drainage, are inclined to overlook the economic phases and to insist that soil drainage, or tile drainage, is necessary at once if profitable returns are to be received from the investment.

When dealing with low-priced agricultural land—land already cleared and cultivated but which has a market value of only $20 to $40 per acre—it is generally difficult to convince the owner that it is advisable to spend $30 to $50 per acre for drainage. He is inclined to say that that is more than the land is worth. He may realize that the crop yield under existing conditions is less than half of what could be expected after tile drainage, but even if he has the money available, he is inclined to spend it on other improvements and gamble that the next year will be a dry one, and that a good crop will be obtained without drainage. If he does not have the money required, he is likely to give up the idea of drainage entirely, as being something he cannot afford. In either case, if the landowner were advised that he could get rid of his surface water by expending a small amount, and thus materially increase the crop yield, he would be tempted to follow the suggestion. Well-planned surface drainage usually results in large returns on the investment, and this tends to "sell" the owner on drainage so that he is ready to listen to recommendations relative to more complete drainage.

The cheapest and simplest method of securing surface drainage is by constructing shallow ditches along low depressions through the fields. This plan, if explained to the farmer, can usually be worked out by him without assistance. The ditches can be made with a plow and slip scraper, a road grader, or with one of the patented ditching plows, when teams are not otherwise engaged. Fig. 1 shows a small V-shaped ditch being constructed with a ditching plow that cost about $90. Fig. 2 shows a road grader and tractor engaged in constructing V-shaped field ditches. Where such equipment is available its use is recommended, as such work can be done rapidly and cheaply by this method. Where a road grader and tractor are not available the use of a ditching plow such as shown in Fig. 1 is recommended.

The ditches should be made with sloping sides and wide enough to be readily crossed with farm machinery. Each rain will reveal the points in the ditch that are too high and these points can be deepened at the next opportunity. Care should be exercised, in excavating, not to leave any low place where the water will stand.

By intelligent and careful ditching the farmer can in the course of a few years, at small expense, put his land in good condition as far as surface drainage is concerned. The benefits received will more than repay the cost involved.

When the time comes to install tile drains it will frequently be found advisable to maintain the shallow, open-ditch system recommended above to take care of the surface water. The ditches assist in quickly carrying off the water from heavy rains, thus making it possible to reduce the size of the main tile lines required to clear the land of water quickly. In the North spring rains can be carried off by the surface drains before the frost is out of the ground sufficiently to permit tile drains to operate. Thus the money expended on open ditches is not wasted even when it is intended ultimately to tile drain the area.

In planning a tile drainage system for low-priced land there is danger that the inexperienced or careless engineer will not make as complete an examination of the land as he should. There is a temptation to just make enough of a survey to insure the fact that sufficient fall is available, and then plan a uniform system of tile drainage, with the result that the estimated cost of the work is more than the value of the land. A more detailed examination may show that there are shallow depressions in the field which, if drained by random lines of tile, would greatly improve the condition of the entire field, and at a comparatively small cost.

I had such an experience in the black prairies of Alabama. After making a survey to determine the general shape and slope of a 20-acre field, I designed and installed a uniform system of tile drains at a cost of $30 per acre. The following year I made a careful examination of a 20-acre tract located across a small creek from the tiled tract. The surface and soil conditions of the two areas were similar in every respect. On the second tract, I carefully located the low swales or seeped areas and drained them with random lines of tile at a cost of about $100, or $5 per acre. Crop records maintained on the two fields for a number of years showed very little difference in yield. Without doubt money was wasted on the first area drained due to the placing of too much dependence on the theory that complete drainage always pays. Many fields can be greatly benefited at comparatively low cost by random lines of tile, provided suitable outlets are available.

It is not the object of this paper to discuss in detail the construction of drainage improvements, but rather to call attention to the fact that complete drainage of a field is not always necessary or advisable; that partial drainage is frequently very profitable; and that the possibilities of such drainage should always be considered in planning drainage.

*Paper presented at the 20th annual meeting of the American Society of Agricultural Engineers, at Lake Tahoe, Calif., June, 1926.

[1]Mem. A.S.A.E. Drainage engineer, U. S. Department of Agriculture.

Fig. 1. (Left) A small V-shaped ditch being constructed with a ditching plow that cost about $90.00. Fig. 2. (Above) Using a road grader and tractor in constructing V-shaped ditches

The Missouri Terracing Frame

By J. C. Wooley[1]

THERE is great need for the terracing of farm lands in Missouri. The soils and the agricultural engineering extension specialists of the University of Missouri have laid out and supervised the construction of a large number of terraces. These terraced fields have served as permanent demonstrations of the value of terraces in preventing erosion.

Farmers in the community not being trained in the use of the level must wait until the extension specialist can visit their farms to stake out terraces, even though they are convinced of their value, and thus the number of terraces constructed is limited.

Any discussion of the methods used in laying out terraces involves the use of such terms as "vertical interval," "variable grade," etc., which immediately gives the farmer the impression that the job is beyond him and in many instances the work is neglected.

The terracing frame described in this article was designed to simplify the process of spacing and laying out and checking terraces, so that the farmer could do this work without so much personal service. No doubt the farmer, in many cases, will need some help in selecting the proper outlets, etc. However, much of this information can be given in a general meeting, and thus many farmers will be able to go ahead with the work of terracing.

The frame shown in Fig. 1 is made twelve feet six inches long. The legs are made three feet high as this is a convenient height for use. An ordinary carpenter's level is fastened to the center of the frame as shown. The vertical interval on any grade divided by the inches fall in 12½ feet on this grade gives the number of steps with the terracing frame between terraces on that particular grade. The curve

[1]Professor of Agricultural Engineering, University of Missouri. Mem. A.S.A.E.

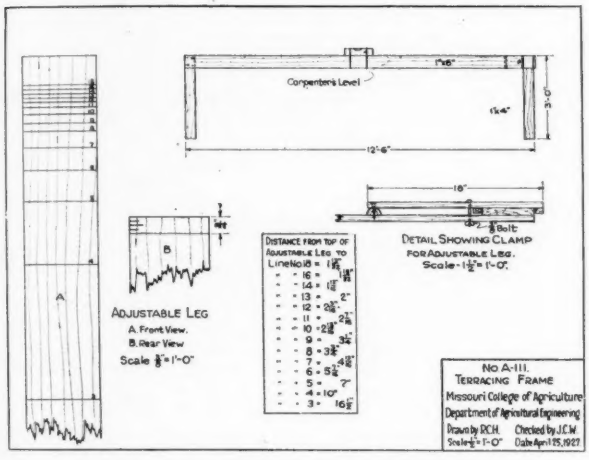


Fig. 1. The Missouri terracing frame

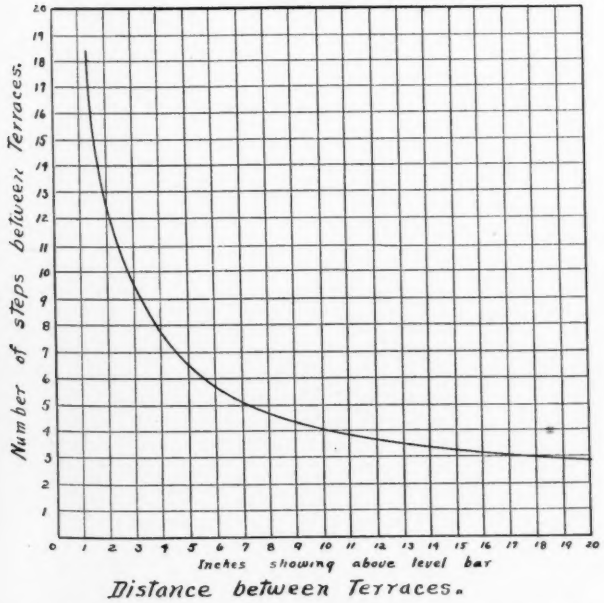


Fig. 2. Curve used to find number of steps between terraces on any grade

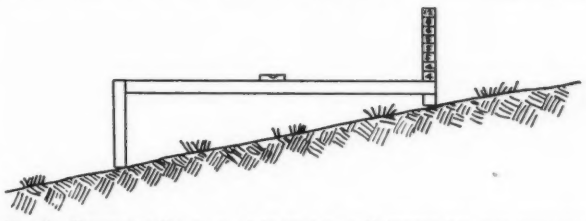


Fig. 3. Terracing frame used to measure distances between terraces

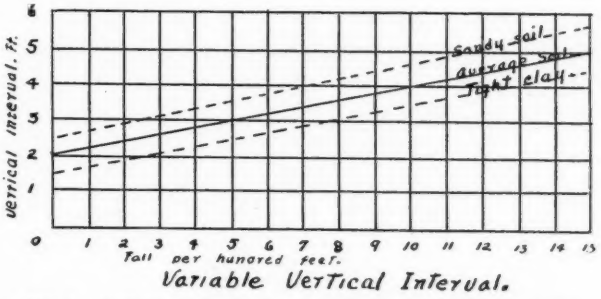


Fig. 4. Variable vertical interval secured with terracing frame

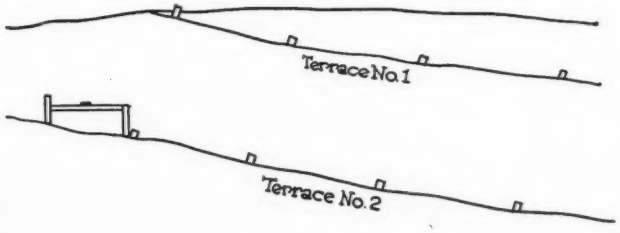


Fig. 5. Terracing frame used for laying of terraces

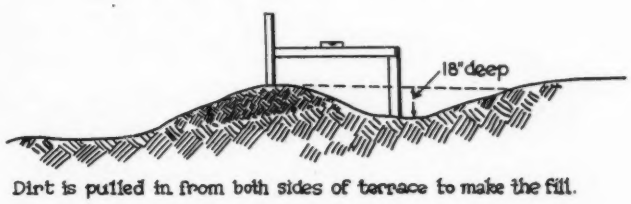


Fig. 6. Use of terracing frame to check completed terrace

in Fig. 2 can be used to find the number of steps between terraces on any grade. It can also be used to graduate the adjustable leg of the frame as shown in Fig. 1. On sandy soil, the number of steps can be increased and on tight clay the number of steps can be decreased.

On the opposite side of this movable leg the first inch is graduated in quarters to be used in laying out terraces. To determine the proper distance—on the surface of the ground—between terraces, set the frame up and down the hill in the direction of flow of the water. Level up by sliding the cross bar down on the movable leg. The smallest number showing above the cross bar on the movable leg is the number of steps, with the frame, between terraces for this slipe. Fig. 3 shows this use of the frame in finding the distance between terraces.

Probably the best practice to determine the vertical interval between terraces has been to provide for a vertical interval of 3 feet for grades up to 5 per cent, a 4-foot vertical interval for grades from 5 to 10 per cent, and a 5-foot interval on slopes from 10 to 15 per cent. Using these points to determine the vertical interval for all grades, we have a variable vertical interval. Fig. 4 shows the vertical interval which results from the use of this frame on different slopes.

After the distance between the outlets has been determined, it is necessary to estimate the length of the terrace. If it is 800 feet long, the first 200 feet may be given one inch fall in 16 feet. Set the adjustable leg with one inch showing above the cross bar. For the second 200 feet set the adjustable leg so that ¾ inch shows above the level bar, etc. A variable grade terrace is thus secured.

A check is needed on the completed terrace to determine the height of the ridge above the trough. To check this depth, adjust the movable leg so that 14 to 18 inches show above the level bar. By setting the long leg in the ditch and the other on the ridge, a check may be obtained.

The Engineer in Agriculture*

By Arthur Huntington[1]

A PATENT attorney, Selden, and not a man skilled in transportation matters made the first automobile; Howe, a skilled machinist, made the first sewing machine; Bell, a teacher of deaf and mutes, the first telephone; Whitney, a lawyer, the cotton gin. A professor of mathematics, Newton, worked out the laws of gravitation before he ever saw a telescope. Kant, a philosopher, suggested the nebular hypothesis to explain the origin of our solar system.

It may seem rather strange that bankers and engineers should be gathered here to make suggestions for the relief of agriculture, but allow me to call your attention to the fact that our greatest developer of new plants was neither a dirt farmer nor a botanist, but an amateur-experimenter; that none of our labor-saving machines in agriculture were developed by farmers. The general public naturally accepts the expert and expects much from him but few workers have invented anything to lighten their toil.

Quite frequently a man inexperienced in the specific field, but with logical brains, possesses pronounced advantages over the experts; he enters the field without prejudices; unhandicapped by preconceived notions, he is less daunted by the opinions adverse to any new innovation that he may originate.

Agriculture has shown itself incapable of solving its own troubles. It has accepted as basic in the industry those things that have proven its undoing. It has accepted itself as a mode of living and not as an industry to be analyzed, and made to coordinate with other industries in the business world.

National wealth is measured in terms of production. Man gets paid for what he produces, little consideration being given to the effort put forth. In America where his production is the greatest, he has attained the highest standards of wealth.

Modern business has paid too much attention to natural resources, soil fertility, density of population, appraised valuation of the property, income and production per acre, and not enough attention to production per worker.

Contrary to general belief America's vast wealth is the direct result of her ability to produce. It is admitted that natural resources are basic, but their value comes only as they enter into production, and production is the function of the engineer. Agriculture has prospered or failed to prosper in almost direct ratio to the use or failure to use the engineer.

The refinement of the industry of agriculture will come largely through some branch of engineering which will provide ways and means of utilizing many valuable products that are now only partially used, or in many instances entirely thrown away. In other words, crop utilization must become a factor in agriculture.

It is the engineer who is now analyzing this complex industry into its component parts, pointing out that which is crop production, that which is animal husbandry, that which is manufacturing, and that which is business.

He is giving to agriculture a cost system which will show the cost of each operation and a balance sheet that will show the profit or loss that goes with production, raising the business standards of the industry, thus making agriculture a part of the business fabric of the country and rescuing it from the domination of the politician, the speculator and the agitator.

Why is it that men who till the soil try to increase their capital account to a maximum by inflating values, thus increasing taxes, rents and all fixed charges, when those who produce that which the farmer must buy produce on the smallest amount of capital possible, thus holding overhead to a minimum.

I could show that cooperative marketing as it is now practiced is not marketing at all, but only a cooperative loading arrangement. Agriculture has no sales organization at the present time but will create one when the engineer has analyzed the industry and shown the terrific drain that the present sales inefficiencies are costing. No industry can rise above its sales organization, and no industry is so badly handicapped by poor selling as agriculture.

Some years ago California was clamoring for the immigration exclusion act, claiming that she could not compete with the cheap labor of China and Japan; she was also asking for a tariff on rice, claiming that labor in China was so cheap that she must have protection.

I was in California in June and July of last year attending the annual meeting of the American Society of Agricultural Engineers. After the meeting we were "shown California". We saw much rice and much of the labor was oriental. We asked what they paid the oriental laborers, and were told $6.00 a day and "found," or the equivalent of $8.00. We asked where they found a market and were told in China and Japan where rice field labor is 15 cents per day.

A little further inquiry brought the information that the Chinese Agricultural Association had a commission in San Francisco protesting against Americans flooding China with cheap rice, thus destroying their agriculture.

It was not the immigration law, for orientals in California do not work for an oriental wage, but work for an American wage. It was not the tariff that made the difference. It was the machinery and practices built up by the American engineer that made it possible.

In China by "hand power" it takes three to five Chinamen

*Abridgment of an address before the Agricultural Commission of the American Bankers Association, at Chicago, December 1, 1926.

[1]Public Relations Engineer, Iowa Railway and Light Corporation. Mem. A.S.A.E.

to raise an acre of rice; in America one Chinaman raises upwards of 100 acres. In China the yield is nearly twice the American yield due to intensive cultivation. The results are that the cost per pound in America is so cheap that it can be laid down in China at a cost so low that a Chinaman cannot compete even at 15 cents per day.

Measured in production an Americanized Chinaman with American equipment at $8.00 per day makes an Asiatic Chinaman without the equipment produced by the American engineer worth less than $8.00 per year.

Going back to my first statement, namely, that man must take his pay in terms of what he produces, it naturally follows that that nation or industry which uses the most efficient machinery and power to multiply the production of a man and makes the best use of the crop that is produced, produces the greatest wealth, has the highest living standards, has the shortest working hours, and the highest wage per worker.

America with her specialized engineers has increased man production thirty-five-fold, whereas her nearest competitor, Great Britain, only multiplies man production twenty-four times. Compare the wealth of the two nations and the wages and the living standards and you will find that roughly the ratio in each instance is somewhere near the ratio of 35 to 24; in other words, the ratio of the use of power and machinery.

Let us compare America with some other nations on this same basis. Canada's production ratio is 22; Belgium, 19; Germany, 15 (Germany's great wealth before the war was the utilization by her chemical engineers of that which she produced); Czecho-Slovakia, 11.5; Austria, 10; France, 9.7; Holland, 7.5; Poland, 4.2; Italy, 3.1; Japan, 2.2; Russia, 1.6; India, 1.4; China, 1.2.

America by the use of power and machinery produces on the average thirty-five times as much per man as a nation without such equipment, but the benefits are not equally shared. Some industries are highly industrialized and some rather backward. Some industries have cheap power while others have expensive power and use it in an inefficient manner.

Agriculture on the average uses high priced animal and human power, whereas the factory that produces that which the farmer must buy has cheap mechanical power.

Ten good healthy men working in mass can exert one horsepower for about an hour, but it will take nearer twenty average men to exert a horsepower continuously over a period of an 8-hour day. Ten men at 30 cents an hour makes a horsepower for one hour cost $3.00; for continuous operation the cost would be $6.00.

A good horse can deliver a horsepower; good authorities agree that it costs from 25 to 35 cents to maintain a horse for each hour of his useful life.

Mechanical power costs for operation around 5 cents per horsepower-hour. China uses man power at from one to 1½ cents per hour, which makes a horsepower-hour cost about 20 to 30 cents.

American agriculture uses animal power directed by man power at about 30 cents per hour, but the Chinaman is equipped with a hoe and the American is equipped with a machine. The American factory is equipped not only with cheap power in unlimited quantities but is also equipped with automatic machinery.

To raise an acre of corn by the use of a hoe requires 300 hours of men labor. To raise it with the aid of one horse requires 100 hours; with two horses, 40 hours; with three horses, 25 hours; with four horses, 15 hours; with five horses, less than 9 hours. With the intelligent use of mechanical power and proper equipment the time and costs can be greatly reduced.

But if a man is going to use this large amount of power he must have large acreage to farm or his overhead will eat him up. You will remember that I said power and machinery "efficiently" used, and to be efficiently used machinery must be proportioned to the size of the farm and the work done.

I do not propose to discuss the efficiency of large and small farms, or the farm as a mode of living against a commercialized agriculture, but I will say that efficiency in agriculture means farms large enough to be commercialized to the point that they can compete with a commercialized factory, which produces that which the farmer buys. The commercialized large farm, right or wrong, must be accepted, for it is a reality.

The trouble with the cotton and tobacco farmers is that

Engineered Transportation

Roy E. Murphy (Assoc. Mem. A.S.A.E.), manager of the famous Deems Horseless Farm, Burlington, Iowa, has "engineered" his hauling operations. The International speed truck is an important time-saving machine on the Deems Farm, on which the major operations are the feeding of hogs and steers. With an all-purpose tractor and other types of tractors the motor truck has made it possible to eliminate all horses on this typical 200-acre corn belt farm. The distance of the farm to the shipping station at Burlington is three and a half miles. Recently Mr. Murphy hauled twenty head of hogs, gross weight 5850 pounds, in three trips in two and a half hours.

both industries are conducted largely as hand-operated industries, thus bringing American labor more nearly to the level of Egypt, India and Turkey.

This influence of power and machinery in agriculture is not something that is peculiar to America and China. It applies to all nations and industries as well as to all branches of agriculture.

But how does agriculture compare with industry? It has improved but hasn't kept pace with the industrialized factory. In 1890 it took about 30 man-hours to raise an acre of corn in the corn belt. In 1900 it took 20 hours, and in 1920 it took 16 hours. The best practice today is about 10 hours.

Compare this with industry, using figures mostly from 1890 and 1920. One man produced:

Without modern machinery

	In 1920
½ ton of coal	4 tons
100 sq. ft. of lumber	750 sq. ft.
500 pounds of iron	5000 pounds
¼ pair of shoes	10 pairs
20 sq. ft. of paper	20,000 sq. ft.
55 sq. ft. of glass	3000 sq. ft.

In nearly every industry production has outrun agricultural production, until today the man of agriculture must work 2.18 hours to produce that which will exchange in the market for that which the man of the factory produces in one hour. As man lives on what he produces and not on the effort put forth, it is plain to see that agriculture producing in small quantities with inferior equipment is at a tremendous disadvantage and will continue to be so until there is a better ratio of exchange between agricultural production and factory production.

Contrary to general belief industry derives no permanent benefit from this unbalanced condition; agriculture is industry's greatest market and when this market is gone the industry must run on short time until the market recovers. Industry is now waiting for agriculture to recover.

How does this condition affect the great corn belt? It is not causing any revolutions nor is it likely to, but it is causing a vast evolution which will continue until the problems of agriculture become industrialized and "businessized" (if there is such a word).

Let us for a moment compare some of the practices in business and maufacturing with the same practices in agriculture.

The factory man keeps his capital account as low as possible in order that his profit may be great for each dollar invested. The man in agriculture accepts with much elation each advance in the selling price of land even when there is no increased earnings. How many men have farmed simply to make a living, with their sole hope of financial independence placed on the increased land values; hoping for the day when they could sell out and retire to some sunny place on "Easy Street". The debts of agriculture must in the last analysis be paid with profits from agriculture and not with high prices either for farm crops or the sale of the land.

The factory man finances himself by pledging the profits from his business whereas the farmer pledges his capital. The banker looks at the earnings in a factory but he has a farm appraised in order that he may know that he can get his money by selling the farm.

The factory man keeps his books in such a way that he knows his overhead, his fixed charges, his permanent capital, his working capital and operates on a balance sheet that he can analyze at any time that he chooses. The farmer takes no account of any of these items although his capital invested per dollar of returns and his overhead are the largest of any of the industries.

The factory figures the total cost, whereas in agriculture costs are figured only as the actual cash money that changes hands.

The factory figures the profit on the business and then lives on the surplus. Agriculture lives and then figures a profit by looking into the bank book to see if there is any cash left.

The factory accepts the price and strives to make a profit at that price, whereas the farmer studies only price and tries to spring it.

The factory strives to increase its output to cut down production costs and sells it into the best market available, whereas agriculture is councilling restricted production to the place that a shortage will increase the price.

The factory man tries to reduce the cost to the place that it will drive his competitor out of business, whereas agriculture concerns itself with making the inefficient farmer remain on the farm, over-producing, and thus holding down the standard of living.

Industries strive to sell into the best markets and will cut the price to hold the customer, whereas agriculture does not know its customer and tries to spring the price by trying to outguess the purchaser.

Industry purchases the best sales ability possible as it realizes that sales ability is hard to get, whereas agriculture has no sales organization and places the handling of its product in the hands of those who have neither sales experience nor sales ability.

Industry established the middleman, whereas agriculture hopes to destroy him.

Industry specializes, whereas the farmer tries to diversify to the point that he many times finds himself in a regular maze of unrelated operations.

Industry accepts the politician only with the view of "using him," whereas agriculture looks to him to solve all of his economic problems and in so doing accepts men who have neither knowledge of the situation nor qualifications to solve the problem if they knew the cause of the trouble.

American agriculture is not going back to peasantry. It is accepting these things that will make it able to compete with those who produce that which agriculture must buy. It has accepted the American agricultural engineer who is designing and giving to the manufacturer to make and distribute, and the farmer to use, the machinery which, when efficiently used, will produce as much value per worker as is produced in the factory. Agriculture cannot prosper until agricultural labor produces on a basis equal to industrial labor, and when that time comes agricultural income will compare favorably with industrial income.

It is accepting the chemical engineer who will find profitable uses for those things in agriculture that are now being either wasted or inefficiently used.

We are establishing machinery to develop crop utilization which must go hand in hand with scientific production. In industry when a surplus comes it is met by a new use or by the development of new customers. In agriculture a surplus is met by restricting the output. Some agricultural leaders have even suggested burning corn already produced. Utilization leads development in industry. Utilization is little considered in agriculture. Corn sugar agitation is one of the first efforts of agriculture to cooperate with industry in the utilization of an agricultural product.

In 1870 America produced and used about 1,000,000 tons of ingot steel, whereas the corn production of Iowa was approximately 100,000,000 bushels. In 1925 we used 70,000,000 tons of steel, and Iowa's bumper crop of corn was only 478,000,000 bushels. The steel output increased seventy fold: corn less then five fold. The output per worker in the steel industry increased about ten fold; the output per worker in corn agriculture was only about three fold. Steel worked on a decreasing price, agriculture on an increasing price, steel on an increasing profit, agriculture on a practical stationary profit. Steel built its prosperity on new uses, agriculture on growth of land values due to a decreased supply.

A utilization era in agriculture is one of the vital factors of the industry at this time and must go hand in hand with scientific and economic production.

In conclusion let me say that the broad acres of the corn belt are susceptible to power farming. They are coming into their own, and under the direction of the agricultural and chemical engineer will become as dominant in the world of agriculture as the American factory is in the world of commerce.

Engineers as Leaders and Pioneers in the New Civilization*

By Dexter S. Kimball[1]

AS I travel around this country I am constantly confronted with the question, Why American Engineering Council? Why are engineers concerned in matters such as lie before us where other professional men are, for the most part, apathetic and take little or no interest in them? Why are we interesting ourselves in political and economic questions that twenty-five years ago or less were considered to be entirely outside the scope of the field of engineering and concerning which the opinions of engineers were considered to be of little or no value? The answer to these questions is more far-reaching than we suspect and takes us back into some very fundamental things.

Ever since man has inhabited the earth his mind has been busy with two great fields of thought. The first concerns the making of a living, providing food, clothing, and shelter and, in general, subduing a rather inhospitable environment to his service. The second field of thought embodies his speculations as to where he came from, what he is here for, and whence he goes when he departs from this mundane existence. And out of our achievements in the one field and our hopes, fears, and aspirations in the other have come what we are pleased to call "ideals." Hence these ideals are always ideals of necessity, for human needs of food, clothing, shelter, and other creature comforts always persist like a great undercurrent beneath our highest idealistic aspirations.

Human progress began when men learned to record their experiences. The spoken word vanishes but the written word endures to enlighten, guide, or entertain succeeding generations. Because Homer wrote down his epics they still delight and sway the minds of men. And because the Emperor Justinian required his consuls to write down their experiences in governing the Roman Empire we all live to this day beneath the shadow of the Roman eagle, for the Justinian code was the beginning of modern law.

Man began very early to record his spiritual experiences and we have an immense volume of these experiences and of his hopes, fears, and spiritual speculations. He is a miserable man indeed who cannot find in this immense and detailed record of human reasoning some kind of a spiritual staff to stay his soul in his earthly wanderings. But on the physical side of this existence, for some reason that we cannot explain, man was very slow to record his observations and experiences, and in the early times when such records were made they were not infrequently lost or destroyed. We do not know, for instance, how many times the scientific method of thought was discovered and lost. Long before the Christian era Eratosthenes demonstrated that the earth was round and measured its diameter within fifty miles of exactness. Yet eighteen centuries afterward Galileo was condemned to prison and death for asserting similar beliefs. And in spite of the fact that we have discovered and rediscovered that the earth is round there are still people living in these United States and claiming to be educated who still believe that the earth is flat. Truly, it is difficult for us who are scientifically educated to believe that such ignorance can still exist among us.

While science and scientific thought are as old as man himself they appear only as a fine thread running through the history of the race until comparatively recent times. Serious efforts to record observed phenomena did not begin until about three hundred years ago. Since that time, however, the growth of recorded knowledge has been tremendous and we have already rolled up a volume of observed facts that is very impressive and the rate of growth of our scientific background shows no sign of decreasing. To one like myself who has lived on a university campus for the past quarter of a century the increase in scientific knowledge and the increase in its applications cannot fail to be impressive; for a great university always reflects quickly all changes in our industrial and social life.

Twenty-five years ago colleges of technology and engineering were doing pioneer work in applied science. They were not highly regarded, but rather tolerated, and the content of their curricula was not looked upon as tending to develop high mental powers. The term "educated plumber" still survives as a term of good natured approbrium upon the Cornell campus. It has been some years now since any of us have felt it to be necessary to apologize for engineering education or for engineers. Both have made a great place for themselves in our national life, and engineering has become one of the learned professions, ranking with law and medicine and of equal importance in our social and political life. In the wake of the trail blazed by medicine and engineering are now seen a long procession of callings repeating the history of these great professions in gathering together a raft of scientific data on which to float themselves above the old mire of superstition, ignorance, empiricism, and prejudice. Veterinary medicine has in one generation lifted itself from a purely empirical and lightly-regarded calling to a rank well up among the professions. Agriculture with its allied callings, animal husbandry, poultry husbandry, horticulture, floriculture, etc., are all making rapid progress and in the great industrial life of the nation there is a movement too great to be ignored toward the application of the methods of the engineer to the solution of all manner of problems. To such a degree has this movement invaded our industrial life that the term engineer has lost all of its original significance and the term engineering has become synonomous with accomplishment and with "getting things done." How far this movement may go we may only guess, but personally I am of the opinion that these methods will finally permeate every nook and corner of our industrial and political life. The scientific method is too powerful a method of solving problems to have metes and bounds set to its application.

Through the application of these methods and their derivatives we have built up a most impressive industrial machine and immense national wealth. In this way only can we account for our industrial success. Vast national resources, of course, are ours but they were also the possession of the Indians who preceded us. From these resources we have developed national wealth to the amount of $300,000,000,000 and a national income of over $70,000,000,000. Never before has any nation possessed such great wealth and never before has the level of individual well-being been so high. If every owner of an automobile in the United States would fill his car with passengers the entire population could go for a ride. And in spite of such apparently luxurious expenditures the deposits in the savings banks rise continuously and men and women in all walks of life are investing in securities of many kinds. More remarkable still, the industrial engineers who have studied our mills and factories are almost unanimous in their reports that the average efficiency of production in this country is not fifty per cent at best. It would appear that we can still rise to higher industrial and social levels and we have gone a long way towards solving the problem of the production of our physical needs.

It was a perfectly natural step for the engineer to extend his methods to the field of industrial administration. A considerable degree of credit must be given to the electrical engineer in introducing engineering methods into actual factory work. The manufacture of electrical apparatus was so markedly different from the production of the older lines of machinery as to call for many new methods and processes which the electrical engineer was required to design and then to instruct workmen in their operation. And when the trained engineer had once found his way from the drawing board to the factory floor, it was quickly recognized that his train-

*President's address at the annual meeting of American Engineering Council, at Washington, D. C., January, 1927.

[1]President, American Engineering Council. Dean, College of Engineering, Cornell University.

ing was of peculiar value in plant lay-out, plant equipment, and plant operation. The work and writings of Frederick W. Taylor and his associates did much to advance this movement and the engineer has made such rapid progress in this field that today his is a predominating influence in plant management. Just as the empirical designing engineer has disappeared before the advance of the scientifically trained man, so the old type of empirical industrial manager and the old time "boss" with his cut-and-try methods are rapidly giving way to more highly trained executives. It cannot but be so since engineering is the backbone and foundation of all industry and as engineering becomes more and more technical, greater technical knowledge must be employed to carry out the engineers' plans.

But the trained engineer has brought something more than technical knowledge with this broader industrial field. Every good engineer is essentially an economist. He deals naturally with the economic problems of design and construction. What is more natural than that he should at once begin to study the economic side of production. Practically all the new economic ideas that have been introduced into industry in the last thirty years have been the work of engineers, and the names of Taylor, Gantt, Gilbreth, Barth, Halsey, Alexander and others have become household words wherever modern industrial management is discussed. And the industrial engineer is now making considerable progress in applying economic theories that have long been known as abstract truths. The law of diminishing returns, for instance, long known as a theory to many engineers is becoming an actual working principle in problems involving quantity production. Incidentally, the graphic methods of the engineer have displaced many of the old methods of presenting facts, and the diagram and chart are well established as business methods.

More important still the modern industrial engineer is questioning closely some of the conclusions of theoretical economists that so far have stood unchallenged. For many years it has been held that low costs were synonomous with low wages and the idea of deliberately paying h'gher wages than competition in the labor market demanded was considered to be unsound. But Taylor proved conclusively that high production, high wages, and low costs can very well be concomitant. Henry Ford deliberately increased the wages of his men considerably above the prevailing wage and prospered and Alexander showed statistically some basic reasons for these startling innovations. How far the modern industrial engineer will go in developing the true economic basis of production remains to be seen, and there is much hope that he will go a long distance in this direction. Nor is this tendency peculiar to engineering. In the field of agricultural economics great progress of a parallel character has already been made and even hotel managers are awakening to the fact that in their work a knowledge of the sciences and economics that underlie the management of great hostelries may well be objects of study for those engaged in that calling.

For the first time, therefore, in human history we appear to have solved in some measure the problem of production. For the first time there is held out to humanity a hope of universal well-being, a state of society where the physical needs of all men can be supplied, at least in some degree of completeness. As Bertrand Russell has truly remarked, if compulsory poverty now exists it does so because we are ignorant. The industrial revolution for the first time in history gave us a large measure of control over our environment. And with that enlarged control has come to many men an enlargement and uplifting of ideals; for modern industrial methods have removed many of the old industrial restrictions which have so long held the industrial workers in bondage. As an illustration witness the modern accident compensation acts and the steady trend toward more humane industrial legislation.

And most important of all is the vision that has come to forward-looking engineers and other workers in the fields of pure and applied science. Looking backward over past achievements, we see the methods of the engineer solving first the physical problems of engineering and production, then, using the same methods, remodeling the administrative methods of industry and now increasing the efficiency of the entire industrial machine by applying old and new economic principles that hitherto have had little or no recognition in actual industrial practice.

Is it not natural that engineers should believe that an extension of their methods into the broader field of governmental administration cannot fail to be helpful wherever engineering methods can be of service? Th's idea began to take form among the membership of our great national engineering organizations fully a quarter of a century ago and has constantly grown in strength. It is reflected clearly in the recorded transactions of all of them and its growing strength is evidenced by the many committees of these organizations that are studying and promoting the educational, administrative, and economic aspects of industry, and it is in this movement that American Engineering Council has its roots and from which it draws its support and sustenance.

I have no illusions as to the results we can accomplish and I am fully aware that the engineer as he stands today has many defects and shortcomings. I have no belief that we can solve all the ills of our social and political life. But I do believe that if the engineer will apply to these problems, insofar as his training and experience may warrant, the same methods that have changed our entire outlook as to the production of wealth he can make a greater contribution to the problem of the distribution of the products and profits of industry than any other profession. Surely here is something to challenge our best engineering minds; surely here is an opportunity to lift the ideals of the race to a height never before attained.

A Boon To Rural Electrification

RURAL electrification with central station current, in far out of the way places, will not only be possible but practical as soon as a recent invention can be commercially applied.

Previous to the invention of this device large amounts of power could not be transmitted on a simple set of wires, over distances much greater than 100 miles, due to power surges which would be set up and which would cause extremely erratic voltage conditions. The new device will increase the capacity of long lines as high as 75 per cent at an expense not greater than 20 per cent of the original cost of the line, according to estimates of the Westinghouse Electric & Manufacturing Company, who control the patent.

The inventor, F. G. Baum of San Francisco, says that his invention will be valuable in permitting the economical transmission of power from distant water falls, and in ultimately making it possible for sparsely settled districts and farms almost anywhere in the United States to enjoy the advantages of electric power. He adds that it would make possible, from an engineering standpoint, the building of a transcontinental transmission system, but that this will never be done because there will be no economic demand for it. It is his belief that the greatest application of this invention will be in the bringing of water power from the Rocky Mountains to the Mississippi Valley, over lines 500 to 1,000 miles long.

Agricultural engineers will find no difficulty in visioning the effect of such an invention in extending rural electrification. Its application will open to them large territories previously not considered on account of their remoteness from available power. Perhaps the secluded rancher with no neighbors within miles may soon enjoy as many of the benefits of electricity as the metropolitan apartment dweller.

Mr. Baum is a hydro-electric engineer and an authority on long-distance transmission. His invention, now in the hands of the Westinghouse Electric & Manufacturing Company, is based on the connection of a plurality of automatically regulated synchronous condensers, at substantially uniformly spaced points, directly to the high voltage transmission lines. A long line is thus divided into a series of short lines, in which the factors which tend toward instability can be readily controlled. This system also opposes the sudden voltage changes which would ordinarily be incident to a sudden change of load at some point on the line.

Research in Agricultural Engineering

A department conducted by the Research Committee of the American Society of Agricultural Engineers

Kinematics and Dynamics of the Wheel Type Farm Tractor*

VI. Supporting Soil Reactions and Drawbar Pull

By E. G. McKibben[1]

THE supporting soil reactions at the front and rear wheels are of primary importance. They determine the steering and tractive abilities of the tractor, thus determining its utility.

Supporting Soil Reaction at Front Wheels. (See R_5 of Fig. 30.) By rearranging the moment equation developed in an earlier article, the following equation is obtained for the moment of R_5 about an axis through C (for the situation shown in Fig. 30):

$$R_5 d_9 = Wx_2 - R_2 d_7 - R_4 d_8 - R_6 d_{10} - P_h x_1 - \frac{Wa_h x_3}{g} + \frac{Wa_v x_4}{g} + I_t \propto_t - I_w \propto_w - F_1 d_{15} \quad \ldots\ldots (27)$$

Therefore,

$$R_5 = \frac{Wx_2 - R_2 d_7 - R_4 d_8 - R_6 d_{10} - P_h x_1 - \frac{Wa_h x_3}{g} + \frac{Wa_v x_4}{g}}{d_9} + \frac{I_t \propto_t - I_w \propto_w - F_1 d_{15}}{d_9} \quad \ldots\ldots (28)$$

If there is no acceleration a_h, a_v, $\propto_t$, and $\propto_w$ will be zero and $\frac{Wa_h x_3}{g}$, $\frac{Wa_v x_4}{g}$, $I_t \propto_t$, and $I_w \propto_w$ will disappear from Equation 28. Since d_7, d_8, d_{10}, and F_1 are usually small, moments $R_2 d_7$, $R_4 d_8$, $R_6 d_{10}$, and $F_1 d_{15}$ are often neglected and Equation 28 written

$$R_5 = \frac{Wx_2 - P_h x_1}{d_9} \quad \ldots\ldots (29)$$

While this is an approximation it is more accurate to write this expression as an inequality thus,

$$R_5 = (\text{or} <) \frac{Wx_2 - P_h x_1}{d_9} \quad \ldots\ldots (30)$$

The importance of Equation 28 is due to the fact that in the case of differential steering a certain minimum value of R_5 is required to give the front wheels sufficient grip for satisfactory steering, and that in the case of front-wheel-drive tractors R_1, and consequently P_h, has a direct relation to R_5. Equation 28 also indicates that increasing P_h or x_1, or decreasing x_2, decreases R_5, thus decreasing the tractive and steering ability of the front wheels.

Supporting Soil Reaction at Rear Wheels. (See R_3 of Fig. 30.) In an earlier section the following equation was developed for the forces perpendicular to the direction of motion of the center of the rear axle (for the situation shown in Fig. 30):

$$R_3 + R_5 - R_2 - P_v - W \cos y_1 - \frac{Wa_v}{g} = 0$$

Therefore,

$$R_3 = W \cos y_1 + P_v + \frac{Wa_v}{g} + R_2 - R_5 \quad \ldots\ldots (31)$$

If the value of R_5 from Equation 28 is substituted in Equation 31, a general equation for R_3 is obtained. However, this results in a very long and complicated equation. By considering only the condition of uniform motion, neglecting R_2, and substituting the right-hand member of Expression 30 for R_5 in Equation 31, a simplified approximation for R_3 is obtained.

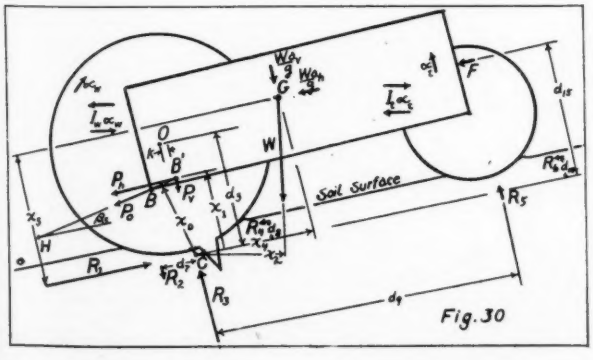
$$R_3 > W \cos y_1 + P_v - \frac{Wx_2 - P_h x_1}{d_9} \quad \ldots\ldots (32)$$

In addition to the assumptions made above, this approximation involves the assumptions made in developing Expression 30.

The importance of Equation 31 is due to the fact that, for rear-drive tractors, R_1, and consequently P_h, have a direct relation to R_3. A study of Equations 28 and 31 indicates that within the limits of stability increasing P_h, P_v or x_1, or decreasing x_2 increases R_3 and thus increases the tractive ability of the rear wheels.

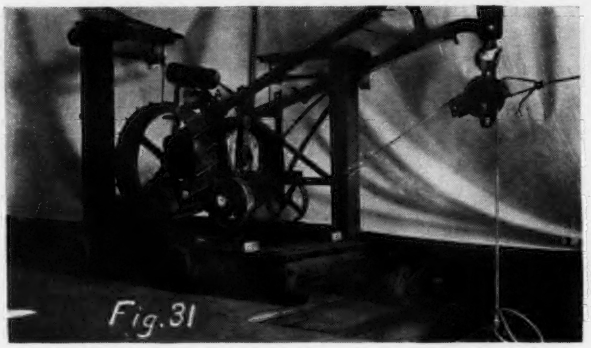
Laboratory Studies. To check Equations 27 to 32 a small garden tractor was placed on platform scales, as shown in Figs. 31 and 32. The front wheels were placed on one pair of scales and the rear wheels on another. The weight, W, of the entire tractor and the weight at the front and rear wheels, W_2 and W_1 was determined. The drivewheels were locked to the frame of the tractor so that they could not turn with respect to the frame. A wire was fastened to the back of each drivewheel and brought under the drivewheel and fastened to the building wall at a point of the same level as E of Fig. 32. One end of a rope was attached to the drawbar and the other end passed through a sheave and fastened to a weight P_o (see Figs. 31 and 32). A three-cornered file was placed under each wheel. The lengths x_o and d_9 and angle β_3 were measured. The weight P_o was increased by known amounts and the corresponding values of R_3 and R_5 were determined by the platform scales. This process was repeated for six values of x_o and two values of β_3.

The values of R_3 and R_5 were computed from the above



[1]Junior agricultural engineer, University of California. Mem. A.S.A.E.

*Sixth of a series of seven articles. The first installment appeared in the January issue. The last article of the series, entitled "Conclusions and Lecture Demonstration Apparatus," will appear in the July issue of AGRICULTURAL ENGINEERING. The material presented in these articles was obtained as the result of an agricultural engineering project of the agricultural experiment station at the University of California. It has been edited and approved by the Research Committee of the American Society of Agricultural Engineers.



equations. In all cases the measured and computed values of R_3 and R_5 checked well within the limits of experimental error.

As a further check of Equations 27 to 32 a study was made of 15-27-horsepower field type tractor. The tractor was placed on the approach of a loading platform as shown in Figs. 33 and 34. The clutch was engaged and the engine flywheel was locked, thus locking the drivewheels. Steel cables were fastened to the backs of the drivewheels, passed under the drivewheels and fastened to the front of the loading platform. Two-inch blocks were placed under the front wheels. Lengths BO′, CO′, CE, OC, d_{12} and angles y_1 and z_1 were measured. From this data lengths d_4, d_9, x_0 and x_2 and angle β_2 were computed by ordinary trigonometrical methods. The values of d_8, d_{12}, β_1, and W used were taken from the results of the location of the center of gravity studies which were made with the same tractor. These values are recorded in Table III.

Table III. (See Fig. 34)

BO′ = 5″	β_2 = 64.5°	d_{12} = 14″
CO′ = 12.5″	d_4 = 11.6″	x_0 = 11.99″
CE = 65″	d_9 = 26.8″	x_2 = 19.23″
OC = 23″	d_9 = 65.28″	y_1 = 14°
β_1 = 6.6°	d_{12} = 65.66″	z_1 = 1.7°

By use of a chain block and an automobile crane a drawbar pull was applied at B parallel to the ground. The drawbar pull was increased until the frame of the tractor had just lifted free from the front axle, thus making R_5 equal to cos y_1 times the weight of the front wheels and axle. The magnitude of this pull was determined by a dynamometer of 3000 pounds capacity and a two-to-one multiplier, and was found to be 5500 pounds. The front wheels and axle were weighed and found to weigh 235 pounds.

Therefore,

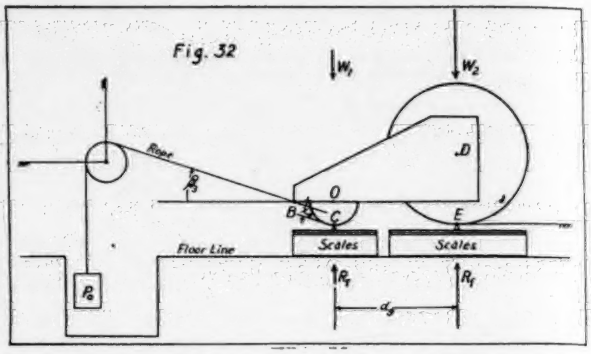
$R_5 = \cos y_1\ (235) = \cos 14\ (235) = 228.02$ pounds

The value of R_5 was computed by substituting in Equation 30, P_0x_0 being used instead of P_hx_1.

$$R_5 = \frac{(4079)(19.23) - (5500)(11.99)}{65.26} = 191 \text{ pounds}$$

Therefore, the difference between R_5 weighed and R_5 computed was (228 — 191) = 37 pounds.

An increase of the dynamometer reading of 3.8 per cent, or a decrease in the experimentally determined value of d_8 of 0.64 inches, or a decrease in the value of k (See Fig. 20) from zero to — 0.61 inches would cause this difference to become approximately zero. Since the measurements of length were made only to the nearest quarter inch, the drawbar pull was read only to the nearest 100 pounds, and the failure of the rear wheels to be true circles might have easily given k some other value than zero, this difference of 37 pounds is easily within the limits of experimental error.



Effect of Cross Grade, Sidedraft, and Offset Drawbar. (See Figs. 35a and 35b.) If the line of action of the load resistance does not lie in the plane perpendicular to the center line of the rear axle through the center point of the rear axle, or if there is a cross grade, the supporting soil reactions against the rear wheels (R_{11} and R_{13} of Fig. 35b) will probably be unequal, although the effect of the offset drawbar and the cross grade may counteract each other.

Using the notation of Figs. 35a and 35b, the following equations may be developed for the situation shown in Figs. 35a and 35b. Considering moments about an axis through C perpendicular to the plane of motion of the center line of the rear axle,

$$W (\sin y_2 \cos y_1)\ x_4 + P_hx_8 - R_{10}d_9 = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots (33)$$

Solving for R_{10},

$$R_{10} = \frac{W (\sin y_2 \cos y_1)\ x_4 + P_hx_8}{d_9} \quad \ldots\ldots\ldots\ldots\ldots\ldots (34)$$

The following facts should be noted concerning Equation 34:

1. If the line of action of P_h passes through C, moment P_hx_8 becomes zero.
2. If the line of action of P_h passes to the other side of C, the direction of moment P_hx_8 becomes reversed.
3. If there is no cross grade, sin y_2 becomes zero and moment $W(\sin y_2 \cos y_1)\ x_4$ becomes zero.
4. If the cross grade is reversed, the direction of moment $W(\sin y_2 \cos y_1)\ x_4$ is reversed.
5. If the moments P_hx_8 and $W (\sin y_2 \cos y_1)$ are opposite in direction, moment $R_{10}d_9$ will have a magnitude equal to their difference and the same direction as the smaller.

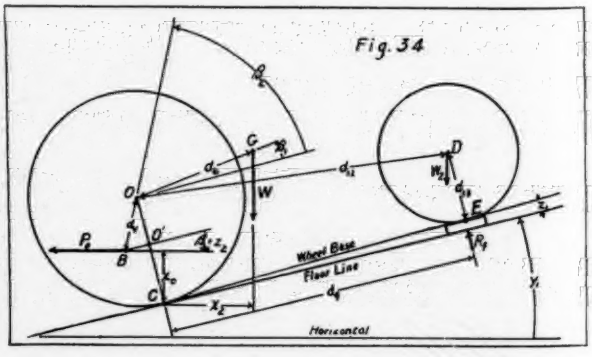
Also,

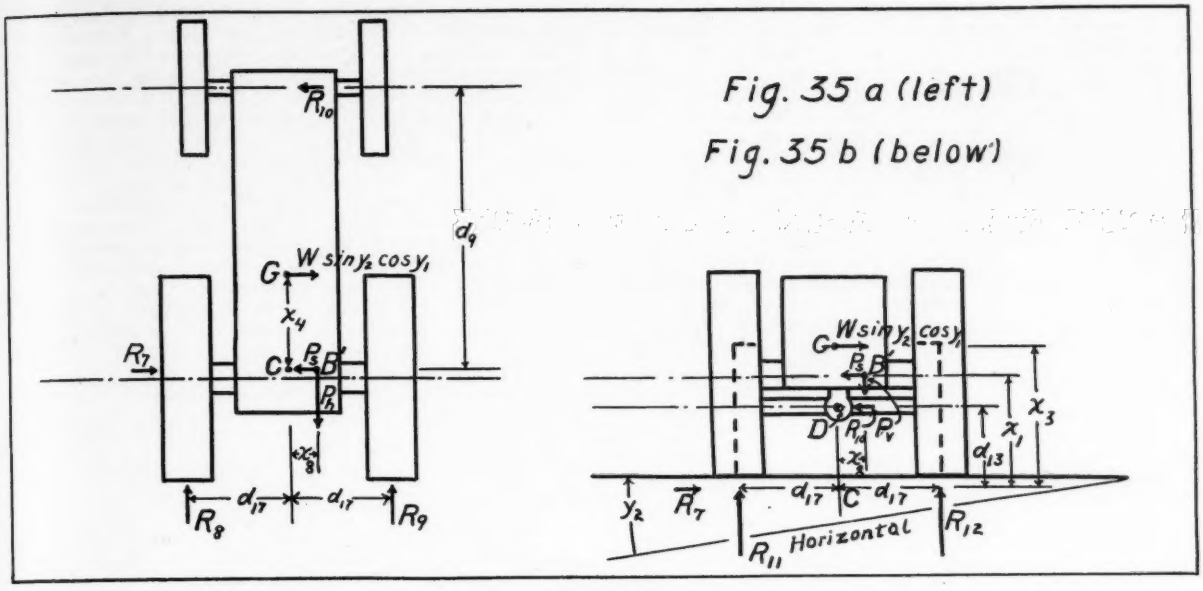
$$R_7 + W (\sin y_2 \cos y_1) - R_{10} - P_8 = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots (35)$$

and

$$R_7 = R_{10} + P_8 - W (\sin y_2 \cos y_1) \quad \ldots\ldots\ldots\ldots\ldots\ldots (36)$$

Substituting for R_{10} its value from Equation 34,





$$R_7 = -W(\sin y_2 \cos y_1) + P_s + \frac{W(\sin y_2 \cos y_1)\, x_4 + P_h x_5}{d_9} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (37)$$

Considering moments about an axis through C parallel to the direction of motion of the center of the rear axle,

$$W(\sin y_2 \cos y_1)\, x_3 + (R_{11} - R_{12})\, d_{17} - R_{10} d_{13} - P_s x_1 + P_v x_5 = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (38)$$

Solving for $(R_{11} - R_{12})$ and substituting for R_{10} its value from Equation 34,

$$(R_{11} - R_{12}) = \frac{W(\sin y_2 \cos y_1) x_4 d_{13} + P_h d_9 d_{13}}{d_{17} d_9} - \frac{W(\sin y_2 \cos y_1) x_3 - P_s x_1 + P_v x_5}{d_{17}} \quad \ldots\ldots\ldots\ldots\ldots (39)$$

A study of Figs. 35a and 35b and Equation 39 indicates the following:

1. A cross grade tends to make the supporting soil reaction greatest against the down grade drivewheel.

2. The component of the load resistance parallel to the rear axle (sidedraft) tends to make the supporting soil reaction greater against the drivewheel toward which the sidedraft acts.

3. If the line of action of the load resistance does not pass through C of Fig. 35a, the component parallel to the direction of motion of the center of the rear axle, P_h, tends to make the supporting soil reaction greater against the further drivewheel, and the component perpendicular to the plane of motion of the center of the rear axle (P_v) tends to make the supporting soil reaction greater against the nearer drivewheel.

4. The effect of a given cross grade, sidedraft, or offset is decreased by increasing the width of the tractor, d_{17}.

5. The effect of a given cross grade is decreased by lowering the center of gravity.

6. The effect of a given sidedraft is decreased by lowering the hitch.

The importance of this phase of the problem is due to the fact that the tractive ability of a tractor using a differential axle is a function of the smaller of the supporting soil reactions against the drivewheels.

Location of Hitch Points. (B and H of Fig. 30.) With a given tractor operating under given field conditions where traction is the limiting factor, the maximum drawbar pull permitting satisfactory operation will be obtained when the supporting soil reaction R_s at the front wheels is just sufficient to enable satisfactory steering, thus allowing a maximum supporting soil reaction, R_s, at the rear wheels for the development of traction. Under different conditions of operation, different ratios between R_s and R_s are most desirable, therefore it should be possible to adjust the hitch so that the proper moment, $P_h x_1$, corresponding to the desired ratio of R_s to R_s may be obtained. In case the line of draft, that is, line HB of Fig. 30, of the implement is parallel to the soil surface, this adjustment may be obtained by making the heights of points B and H adjustable. In case the implement has a definite line of draft which is not horizontal, this line of draft may be maintained and the proper moment, $P_h x_1$, attained if the height of B and the length of d_2 are adjustable.

Also if there is any possibility of P_h becoming numerically greater than $\frac{W x_2}{x_1}$, points B and H should be so located that, when on the steepest grade upon which the tractor is to work, the ratio $\frac{x_2}{x_1}$ will increase as the front of the tractor starts to rise.

Notations for Figs. 35a and 35b

B', point of intersection of line of action of load resistance with plane through line of action of R_7 perpendicular to direction of motion of center of rear axle
C', point on line of action of R_7, midway between rear wheels
D, center of pivot bolt of front axle
P_h, component of load resistance parallel to the direction of motion of the center of the rear axle, when the load resistance is assumed as acting at B'
P_v, component of the load resistance perpendicular to the plane of motion of the center of the rear axle, when the load resistance is assumed as acting at B'
P_s, component of load resistance parallel to the rear axle, when the load resistance is assumed as acting at B'
R_7, component of soil reaction against rear wheels parallel to the rear axle
R_s, tractive soil reaction against left wheel
R_s, tractive soil reaction against right wheel
R_{10}, component, parallel to rear axle, of front axle pivot bolt reaction against tractor frame
R_{11}, supporting soil reaction against left wheel
R_{12}, supporting soil reaction against right wheel
W, weight of entire tractor
W sin y_2 cos y_1, component of W parallel to rear axle
W sin y_1 cos y_2, component of W perpendicular to the plane of motion of the center of the rear axle
d_9, moment arm of R_{10} about an axis through C (Fig. 35a)
d_{13}, moment arm of R_{10} about an axis through C (Fig. 35b)
x_1, moment arm of P_s about an axis through C (Fig. 35b)
x_3, moment arm of W sin y_2 cos y_1 about an axis through C (Fig. 35b)
x_4, moment arm of W sin y_2 cos y_1 (Fig. 35a)
x_5, moment arm of P_h about an axis through C (Fig. 35a) and of P_v (Fig. 35b)
y_1, angle of road grade (not shown)
y_2, angle of cross grade

Implements Attached Rigidly to the Tractor. In the case of implements fastened rigidly to a tractor it is possible for x_1 to be very small. In fact in the case of certain tillage implements, x_1 may even become negative. Thus, if a tractor is designed for implements pulled with a flexible hitch, the weight distribution will not be correct for implements attached rigidly to its frame in such a way as to make x_1 negative, unless the tractor also carries some of the weight of the attached implement in such a location as to cause the proper redistribution of weight between the front and rear wheels.

Therefore, if any implement is to be rigidly attached to a tractor, or a large part of its weight supported by a tractor, the effect upon the location of the center of gravity of the complete outfit and upon the magnitude and sign of x_1 should be studied. This is particularly true if the weight of the attached implement is large compared to that of the tractor, or if it will require a large portion of the tractor's available tractive power.

Also, tillage implements rigidly attached to the tractor frame will support some of the weight of the tractor, when the drivewheels drop into a depression in the soil or for any reason start to slip, unless the depth adjustment of the implement is very quickly changed by a watchful operator. If the implement supports part of the weight of the tractor, R_3 and consequently the tractive ability of the tractor, is reduced. This in turn increases the slippage.

Location of Drivewheels. All statements which have been made apply to rear-wheel-drive tractors. With only slight modifications they can also be applied to front and four-wheel-drive tractors. However, it should be noted that, in the case of the front-wheel-drive tractor and the four-wheel-drive tractor, with a differential between the front and rear wheels, it is impossible for the turning moment of a load resistance, developed by traction, to cause the front wheels to rise from the ground.

Component of Drawbar Pull Parallel to Direction of Motion of the Center of the Rear Axle. The magnitude of the component, parallel to the direction of motion of the center of the rear axle, of the maximum sustained drawbar pull is limited by the drivewheel torque, the stability of the tractor, or the traction.

If the drivewheel torque is the limiting factor, and

T = torque of engine,

r = ratio of crankshaft revolutions to drivewheel revolutions,

e = efficiency of transmission,

for the situation shown in Fig. 30,

$$T\,r\,e + R_4(d_3 - d_8) = R_1 d_3 + R_2(d_7 - k) + R_3 k \quad \ldots\ldots (40)$$

Solving for R_1,

$$R_1 = \frac{T\,r\,e + R_4\,(d_3 - d_8) - R_2(d_7 - k) - R_3 k}{d_3} \quad \ldots\ldots (41)$$

Transposing a force equation developed in a preceding article,

$$P_h = R_1 - R_4 - R_6 - W \sin y_1 - \frac{W a_h}{g} - F_1 \quad \ldots\ldots (42)$$

Substituting for R_1 its value as given in Equation 41,

$$P_h = \frac{T\,r\,e + R_4\,(d_3 - d_8) - R_2(d_7 - k) - R_3 k}{d_3} - R_4 - R_6 - W \sin y_1 - \frac{W a_h}{g} - F_1 \quad \ldots\ldots (43)$$

It would be possible to obtain a combination of conditions which would result in F_1, R_2, R_4, R_6, a_h, k and y_1, each becoming zero. Under these conditions P_h would be a maximum and Equation 43 would become

$$P_h = \frac{T\,r\,e}{d_3} \quad \ldots\ldots (44)$$

It should be noted that, for the situation shown in Fig. 30, any condition which increases $R_2(d_7 - k)$, $R_3 k$, R_4, R_6, $W \sin y_1$, $\frac{W a_h}{g}$ or F_1 decreases the drawbar efficiency of the tractor.

In this connection it should also be noted that exceedingly high temporary values of T may be obtained, the only limits being the speed with which the clutch can be engaged, the gripping power of the clutch, and the strength of the various shafts and gears involved, for as the time taken to bring a rotating flywheel to rest approaches zero the torque required approaches infinity. Thus, if a tractor is equipped with a quick-acting, powerful clutch, and if I_w is large and traction conditions are good, the sudden engagement of the clutch, even with the engine at normal speed, is very apt to disturb the stability of the tractor. If in addition either angle y_1 or length x_1 is large the danger of overturning the tractor is very great. The greater the angular velocity ω_e of the engine crankshaft, and the greater the moment of inertia, I_e, of the flywheel and engine crankshaft, the greater the danger. Since the energy of the flywheel is one-half $I_e\omega_e^2$, the effect of engine speed is directly proportional to its square.

If the stability of the tractor is the limiting factor the situation is defined by the moment equation. Solving the moment equation for the situation shown in Fig. 30, for P_h,

$$P_h = \frac{(W x_2 + \frac{W a_v x_4}{g} + I_t \alpha_t) - (R_2 d_7 + R_4 d_8 + R_5 d_9}{x_1} + \frac{R_e d_{10} + \frac{W a_h x_4}{g} + I_w \alpha_w + F_1 d_{15})}{x_1} \quad \ldots\ldots (45)$$

Before the stability of the tractor is disturbed, R_5 and R_6 must become zero. Also inertia forces due to accelerations are only temporary and must be discarded when considering a sustained drawbar pull. Therefore, if stability is the limiting factor,

$$P_h = \frac{W x_2 - (R_2 d_7 + R_4 d_8 + F_1 d_{15})}{x_1} \quad \ldots\ldots (46)$$

It is possible to obtain a combination of conditions which will cause R_2, R_4, and F_1 to become zero. Under these conditions Equation 46 will become,

$$P_h = \frac{W x_2}{x_1} \quad \ldots\ldots (47)$$

and P_h will have a maximum value when angle y_1 and length x_1 (See Fig. 30) are such as to give a maximum value to $\frac{x_2}{x_1}$. Thus it is evident that, where stability is the limiting factor, any change which increases the value of the ratio $\frac{x_2}{x_1}$ or decreases the value of $R_2 d_7$, $R_4 d_8$, or $F_1 d_{15}$ increases the maximum possible sustained value of P_h.

If the traction is the limiting factor and u represents the maximum ratio of R_1 to R_3 for rear wheel tractors and of R_1 to R_5 for front wheel tractors (neglecting the air resistance and limiting the situation to conditions of uniform motion), a force equation developed in an earlier section may be transposed as follows (See Fig. 30):

$$P_h = R_1 - (R_4 + R_6 + W \sin y_1) \quad \ldots\ldots (48)$$

For rear-wheel-drive tractors $R_3 u$ may be substituted for R_1 in Equation 48.

$$P_h = R_3 u - (R_4 + R_6 + W \sin y_1) \quad \ldots\ldots (49)$$

If the approximate value for R_3 of Expression 32 is substituted for R_3 in Equation 49,

$$P_h > u W \cos y_1 + u P_v - \frac{u x_2 W - u x_1 P_h}{d_9} - (R_4 + R_6 + W \sin y_1) \quad \ldots\ldots (50)$$

Substituting $P_h \tan \beta_2$ for P_v and solving for P_h,

$$P_h > \frac{W(u d_9 \cos y_1 - d_9 \sin y_1 - u x_2) - d_9 R_4 - d_9 R_6}{d_9 - u d_9 \tan \beta_2 - u x_1} \quad \ldots\ldots (51)$$

From Equation 51 the following facts are evident:

1. Increasing the weight W increases the possible value of P_h.
2. Increasing the tractive ratio u increases the possible value of P_h.
3. Increasing the effective grade y_1 decreases the possible value of P_h.
4. Within the limits of stability decreasing x_2 increases the possible value of P_h.
5. Within the limits of stability increasing x_1 increases the possible value of P_h.
6. Increasing angle β_2 increases the possible value of P_h.

For front-wheel-drive tractors uR_2 may be substituted for R_1 in Equation 48,

$$P_h = uR_2 - (R_4 + R_6 + W \sin y_1) \quad \ldots\ldots\ldots\ldots\ldots\ldots (52)$$

If the approximate value of R_2 from Expression 30 is substituted for R_2 in Equation 52,

$$P_h < \frac{uWx_2 - pP_hx_1}{d_9} - (R_4 + R_6 + W \sin y_1) \quad \ldots\ldots\ldots\ldots (53)$$

Simplifying Equation 53 and solving for P_h,

$$P_h < \frac{W(ux_2 - d_9 \sin y_1) - d_9R_4 - d_9R_6}{d_9 + ux_1} \quad \ldots\ldots\ldots\ldots\ldots (54)$$

From Equation 54 the following facts are evident:

1. Increasing the value of W increases the possible value of P_h.
2. Increasing the value of u increases the possible value of P_h.
3. Increasing the value of x_2 increases the possible value of P_h.
4. Increasing the effective grade decreases the possible value of P_h.
5. Increasing angle β_3 provided there is no change in x_1 has no effect upon P_h.
6. Increasing x_1 decreases the possible value of P_h.

It should be noted that, if due to a cross grade, sidedraft, or an offset drawbar, the supporting soil reactions against the drivewheels are not equal, and the tractor has a differential axle; twice the smaller should be substituted for the resultant of the supporting soil reactions in Equations 48 to 54.

Since $\frac{T\,r\,e}{d_3}$ of Equation 37 for any tractor of a given weight may be increased to any desired value by increasing r, and since $\frac{Wx_2}{x_1}$ of Equation 40 may be increased to any desired value by increasing ratio $\frac{x_2}{x_1}$, traction is the final limiting factor in determining the maximum value of P_h. Also, since a high value of P_h is often very desirable, a tractor should be so designed that the gear ratio in low will be great enough, and the hitch point may be lowered enough to make traction the limiting factor in determining the maximum horizontal component of the load resistance.

Effect of the Sudden Stopping of Tractor. The values of P_h shown in Equations 51 and 54 are the maximum values which may be maintained by means of traction and the torque of the engine. However, P_h may be greatly increased if the tractor is suddenly decellerated by a sudden increase in the load resistance. Under these conditions, if $x_1 = x_3$ (See Fig. 30), $\frac{Wa_h}{g}$ will have no effect upon the stability of the tractor; if $x_1 > x_3$, force $\frac{Wa_h}{g}$ will decrease the stability of the tractor; and if $x_1 < x_3$, force $\frac{Wa_h}{g}$ will increase the stability of the tractor. If a tractor is connected to a tillage implement with a hitch which, to all practical purposes, is fixed with respect to its length, and the tillage resistance is suddenly increased, such as striking a large root or stone, all parts of the implement, hitch and tractor are subjected to increased stresses due to the force $\frac{Wa_h}{g}$. The amount of this increase is dependent upon the amount of the increase in the tillage resistance, the weight of the tractor, and rigidity of the implement, hitch and tractor parts. If the increase in the load resistance is large enough and the implement, hitch and tractor parts are rigid enough, some part must fail, for as the distance in which the tractor is stopped approaches zero, the force required approaches infinity.

For any given situation the maximum increase in P_h, represented as P'_h, which will result from the force, $\frac{Wa_h}{g}$ due to the sudden stopping of the implement, if no part of the implement, hitch or tractor is stressed beyond the elastic limit, will be proportional to the distance the tractor moves after the implement is suddenly stopped.

If S = speed of tractor in miles per hour,
W = weight of tractor in pounds, and
x_9 = distance in feet tractor moves after implement is stopped,

then $\frac{(W)(5280)^2(S)^2}{(2)(32.2)(60)^4} \approx (.0334)(W)(S)^2 \approx$ kinetic energy of the tractor in foot-pounds $\ldots\ldots\ldots\ldots\ldots\ldots (55)$

and $\frac{(P'_h)}{(2)}(x_9) \approx (.0334)(W)(S)^2$

$$P'_h \approx \frac{(.0167)(W)(S)^2}{x_9} \quad \ldots\ldots\ldots\ldots\ldots\ldots (56)$$

$$x_9 \approx \frac{(.0167)(W)(S)^2}{P'_h} \quad \ldots\ldots\ldots\ldots\ldots\ldots (57)$$

Thus if a tractor weighing 3000 pounds and moving at 3 miles per hour is stopped in a distance of 0.1 foot, the increase, above tractive ability, in the drawbar pull, P'_h will be

$$P'_h \approx \frac{(.0167)(3000)(3)^2}{.1} \approx 4509 \text{ pounds}$$

If P'_h is to be limited to 2000 pounds for this situation, the distance required to stop the tractor, x_9, must be equal to or greater than,

$$x_9 \approx \frac{(.0167)(3000)(3)^2}{2000} \approx 0.225 \text{ feet.}$$

Equation 56 indicates that the increase in the component of the drawbar pull, due to force $\frac{Wa_h}{g}$ caused by a sudden stopping of the tractor, is proportional to the weight of the tractor and the square of the speed of the tractor, and inversely proportional to the distance required to stop the tractor.

Limiting the Load Resistance by the Use of a Drawbar Spring. By using the proper spring the maximum value of the increase in the component parallel to the direction of motion of the center of the rear axle of the load resistance above the maximum tractive ability may be limited to any desired value.

If P_h = maximum value of horizontal component of the load resistance due to traction,
P'_h = maximum value of increase in load resistance due to sudden stopping
$P_h + P'_h$ = maximum value of horizontal component of total load resistance
F_z = force required to compress spring
x_9 = compression of spring due to P'_h
x_{10} = compression of spring due to P_h
$x_{11} = x_9 + x_{10}$ = total compression of spring

$$F_z = P_h + P'_h = P_h + \frac{(.0167)(W)(S)^2}{x_9} \quad \ldots\ldots\ldots\ldots\ldots (58)$$

$$x_{10} = \frac{x_9P_h}{P'_h} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (59)$$

$$x_{11} = x_9 + x_{10} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (60)$$

For example, if $P_h = 2000$; $W = 3000$; P'_h is to be limited to 2000; and if the maximum value of $S = 3$, then $F_s = 2000 + 2000 = 4000$ pounds.

$$x_9 \approx \frac{(.0167)(3000)(3)^2}{2000} \approx 0.225 \text{ feet (See Equation 57)}$$

$$x_{10} \approx \frac{(.225)(2000)}{2000} \approx 0.225 \text{ feet. (See Equation 59)}$$

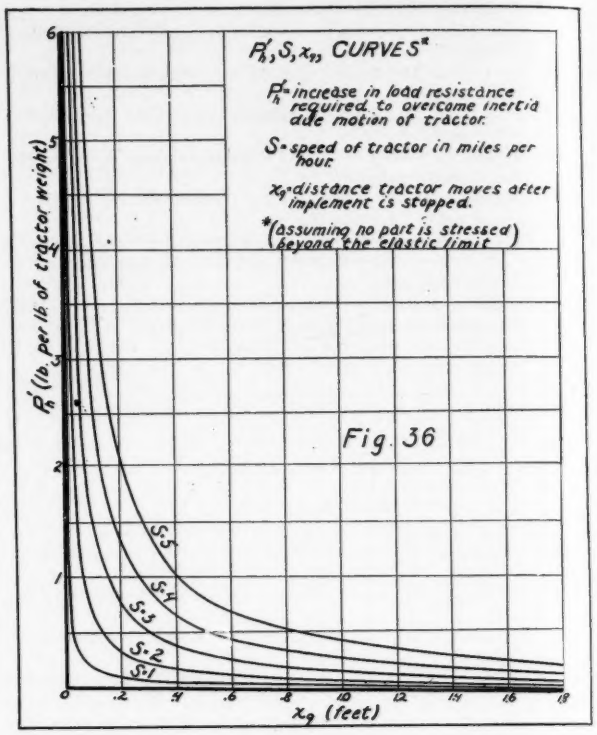
$x_{11} \approx .225 + .225 \approx 0.45$ feet. (See Equation 60)

and, a spring which requires a force of 4000 pounds to compress it 45 feet must be used.

In Fig. 36, the increase above tractive ability, in the component of the load resistance parallel to the direction of motion of the center of the rear axle, P'_h, per pound of tractor weight, due to the sudden stopping of the tractor, is plotted against the distance, x_9, which the tractor moves after the implement is stopped, for tractor speeds of 1, 2, 3, 4 and 5 miles per hour. This figure shows clearly the effect of suddenly stopping a tractor which is moving at a relatively high speed and indicates the necessity of using a spring drawbar, or some type of overload release in the hitch or implement, when using an implement at high speed under conditions where there is a possibility of a sudden large increase in the load resistance.

Relation to Soil Dynamics. Insofar as they affect the location, direction, and magnitude of the soil reactions against the wheels, the dynamical qualities of the soil affect the dynamics of the tractor. Therefore, any study of soil traction dynamics should be directed toward securing information concerning the location, direction, and magnitude of the soil reactions against the tractor wheels.

(The last article of this series will appear in the July issue.)


P'_h, S, x_9 CURVES*
P'_h = increase in load resistance required to overcome inertia due motion of tractor.
S = speed of tractor in miles per hour
x_9 = distance tractor moves after implement is stopped.
*(assuming no part is stressed beyond the elastic limit)
P'_h (lb. per lb. of tractor weight)
x_9 (feet)
S-5
S-4
S-3
S-2
S-1
Fig. 36

Important Factors in Flood Control

THE greatest flood disaster this country has ever known is bringing a realization of the need for a well-established policy of flood prevention, says the U. S. Department of Agriculture in calling attention to two important factors in the control of the rapid run-off of water—reforestation and the reduction of soil erosion. The importance of forests in this respect has long been emphasized, but until recently very little attention has been given to the effect of the continued destructive washing of large areas of cultivated farm land and pasture lands. If proper attention were given to reforesting rough lands unsuited to agriculture, to maintaining good forest cover at the headwaters of rivers, and to the prevention of rapid run-off on all sloping farm lands, it is believed the problem of flood control would be less difficult.

"Reforestation and forest protection," say E. A. Sherman, associate forester of the U.S.D.A. Forest Service, "will unquestionably enter into any plan for the future control of the Mississippi. Claims that the present flood is due to forest destruction or claims that reforestation has no bearing upon flood prevention are both exaggerations. Every acre of land in the immense catchment basin of the Mississippi system contributes, in one form or another, at one time or another, to the flood problem. It is idle to say the scores of millions of acres of forest land within this basin have no relation to the flood problem. The plans for preventing a recurrence of a flood of this magnitude must, as one of their essential factors, include the reforestation of the headwaters of the Mississippi and its tributaries."

"Failure to hold the absorptive surface soil of fields and pastures aaginst the denudation of erosion," says H. H. Benneth of the U.S.D.A. Bureau of Soils, "has contributed to a much more rapid removal of the water that fall upon these eroded lands. The mellow top soil that is gone was far more retentive of moisture than the comparatively impervious subsoil that sheet erosion has left behind." Mr. Bennett believes this wastage of the soil has as much to do with the constantly increasing floods as all other factors. He says that many streams, navigable a generation ago, are now clogged with soil debris. He gives as examples of such clogged rivers the Coldwater and Tallahatchie of northern Mississippi.

"Failure to build terraces on sloping fields generally and to plant grass and trees on the steeper lands highly susceptible to rain wash," says Mr. Bennett, "accounts for much of the excess of water now sweeping down the Mississippi. If this kind of soil wastage on an enormous scale is hot stopped, there is little likelihood that floods will be controlled. Practically nothing is being done about this phase of flood prevention. There are no hillside terraces north of the Arkansas River. Eighteen inches of top soil has been removed from the youthful fields in some parts of northeastern Kansas. The entire top soil is gone from hundreds of thousands of acres in western Virginia, western Pennsylvania, eastern Kentucky and southeastern Ohio. From these lands rain water courses much faster to the Mississippi than formerly. Terraces and grass woodlots, forests, and other soil-binding and soil-building crops will vastly improve the flood situation. Not only will they slow the run-off of water, but they will save the most valuable part of the soil and will reduce the clogging of streams which cuts down their carrying capacity, and adds to the flood danger."

The particular flood prevention recommendation of the Department of Agriculture may be summed up briefly as follows: The general reduction of soil erosion to prevent rapid run-off and the clogging of streams; largely increased efforts by the states and federal government and private owners for coperative forest fire control; largely increased programs for public forests on tributary tree planting on denuded forest lands; encouragement of farmers and otehr land owners, through state and federal aid, to plant trees on rough lands and along water courses; and a study of the possibilities of restoring some of the bottom lands to their original condit'on as carrier of flood waters and producers of forests and game.

Agricultural Engineering Digest

A review of current literature on agricultural engineering by R. W. Trullinger, specialist in agricultural engineering, Office of Experiment Stations, U. S. Department of Agriculture

The Use of Artificial Illumination on New Jersey Poultry Farms, W. H. Allen (New Jersey Stas. Hints to Poultrymen, 14 (1926), No. 12, pp. 4).—Data based on questionnaires are presented showing the November to April production in 286 New Jersey poultry flocks. The flocks have been grouped according to the practice with reference to the use of electric lights. The average production per bird was 67.1 eggs for the flocks using no lights and 75.8 eggs where lights were used.

When lights were supplied for one hour late in the evening in the so-called "evening lunch" system the production averaged 71.9 eggs as compared with 77.2 when the day was lengthened to 12 hours by morning lights, and 75.9 eggs when the length of day was made similar by the use of both morning and evening lights.

Various factors related to the artificial lighting of poultry houses are discussed.

Soil Erosion From Early Plowed Wheat Land, F. L. Duley (Journal American Society of Agronomy, 17 (1925), No. 11, pp. 731-734).—Studies conducted at the Missouri Experiment Station are reported which showed that under the conditions existing at the station the increased loss of soil by erosion due to early plowing for wheat may be considerable, and during this period has been slightly more than that during the rest of the year. On the whole, however, erosion from wheat land is not extremely serious, being only about half as much as from corn land. Where wheat follows another crop like corn or soy beans, and is itself followed by clover, the erosion is very greatly reduced. It is considered likely that on rolling lands in regions of rather high August and September rainfall it will be found more advisable to adjust the rotation so that the land will be covered with a crop practically all the time, rather than to emphasize the advantages of early plowing.

A Portable Poultry House for the Farm (Northern Ireland Ministry of Agriculture Leaflet 21, rev. (1927), pp. 4, pl. 1).—Practical information is given on the planning and construction of a portable poultry house for farms in northern Ireland, together with working drawings and a bill of materials.

Water Works Practice (Baltimore: Williams & Wilkins Co., 1925, pp. XX, 790, figs. 50).—This is a manual of information on water works practice issued by the American Water Works Association. It contains sections on collection of water, quality of water supply, treatment of water, distribution of water, financing and management, and fire protection, together with an introduction and appendix.

Synthetic Motor Spirit From Mixtures of Carbon Monoxide and Hydrogen, (translated title) E Audibert (Chimie et Industrie [Paris], 13 (1925), No. 2, pp. 186-194; trans. in Fuel, 5 (1926), No. 4, pp. 170-177).—Experiments are reported which draw attention to the catalytic activity of binary compounds containing oxygen having sufficient reducing power to oxidize spontaneously in air. These unsaturated compounds bring about the hydrogenation of carbon monoxide. Mixtures of carbon monoxide and hydrogen were found to undergo with suboxides the change expressed by the equation $CO_2 + 2H_2 = CH_3OH$, from which it is calculated that 82 per cent of the calorific value of the gas may be recovered in the form of liquid fuel.

Stack and Grain Drying, W. Aitkenhead (Indiana Station Circular 139 (1926), pp. 4, figs. 5).—The results of experiments on stack and grain drying are briefly presented, together with a description of the equipment used. The equipment followed the same general plan as that developed by the Institute of Agricultural Engineering at Oxford University, with the exception that the hot gases of combustion are mixed with the air blown into the stack. Two alfalfa and two soy bean stacks were dried. The stacks were built over a conical pole frame, and an air trench eighteen inches square led into the center of the cone.

The necessity for evenness in building was indicated, as after four hours blowing parts of a 5-ton alfalfa stack, which permitted an easy passage of air, were dry clear to the outside, while the dense hay was still damp thirty inches from the outside.

A twelve-ton stack of soy bean hay was greatly overdried by eleven hours of blowing. An eight-ton stack of soy beans was well dried in five hours blowing with the ingoing air at 150 degrees Fahrenheit. A heavy shower preceded the building of a ten-ton alfalfa stack from hay in the swath. This stack was blown 7.5 hours with air at a temperature of 162 degrees, and, due to uneven building, it dried in a somewhat patchy manner. However, when taken down two days later it was well fit for the mow.

The Gas Engine on the Farm.—III, Running Troubles and Their Remedy, F. G. Behrends and F. L. Fairbanks (New York Agricultural College) (Cornell) Extension Bulletin 147 (1926), pp. 48, figs. 26).—Practical information on the subject is presented.

Elements of Heat-Power Engineering.—Part I, Thermodynamics and Prime Movers, W. N. Barnard, F. O. Ellenwood, and C. F. Hirshfield (New York: John Wiley & Sons; London: Chapman & Hall, 1926, 3. ed., pp. XII + 493, pls. 3, figs. 257).—This is the third edition of Part I of this book. It contains chapters on fundamentals regarding energy and its transformation; historical outline; illustrations of modern power plants; energy equations; equilibrium, reversibility, and availability; entropy; the properties of gases; thermodynamic processes of gases; the indicator diagram; compressed air; gas cycles; efficiencies and performances of engines; internal-combustion engines—types and mechanical features; internal-combustion engines—actual operation, power, and performance; properties of vapors; thermodynamic processes of vapors; the simple cycles of vapor engines and vapors; the reheating, regenerative, and binary cycles; the reciprocating steam engine; and steam turbines—general.

Sampling and Testing of Highway Materials, W. H. Barton, Jr., and L. H. Doane (New York and London: McGraw-Hill Book Co., 1925, pp. IX + 355, figs. 83).—This book contains chapters on laboratory practice; sampling; portland cement, portland cement concrete and paving brick; aggregates; miscellaneous materials; bituminous materials; specifications; curves, diagrams, and tables; and subgrade soils.

The Farm Water Supply.—Part II, The Use of the Hydraulic Ram, F. G. Behrends (New York Agricultural College (Cornell) Ext. Bul. 145 (1926), pp. 28, figs. 16).—Practical information on the installation, operation, and use of the hydraulic ram in farm water supply systems is presented, together with numerous diagrammatic illustrations.

Earth Pressures on Culvert Pipes, G. M. Braune (U. S. Department of Agriculture, Public Roads, 7 (1927), No. 11, pp. 222-229, figs. 18).—The progress results of a series of tests being conducted at the University of North Carolina to determine earth pressures on culvert pipe, using conditions conforming to practice as closely as possible, are reported.

Tests of four sections of 30-inch cast iron pipe, 2.5 feet long and one inch thick, so placed as to permit a 50 per cent projection, showed that the earth pressure on the test pipe was 84 per cent of the weight of the earth prism immediately over the pipe. This ratio remained practically constant for the entire height of the fill except for the first four feet, where the earth pressures were greater than the weight of the earth prism.

In a test using a 50 per cent projection and a clay fill, the pressures were found upon completion of the embankment to be less than for the projection condition, the ratio of the pressure to the weight of the prism over the pipe decreasing as the fill was raised. The pressures decreased from March to the middle of August, and sudden variations in the weather had but little effect on the pressure.

Combined Concrete and Timber in Flexure, G. D. Burr. (Washington [State] University, Engineering Experiment Station Bulletin 37 (1926), pp. 22, figs. 15).—The results of studies of concrete and timber in flexure are reported, the results of which indicate that timber may be made to take the tension and concrete the compression in a structural member, thus using both materials to their greatest advantage. It was found that concrete and timber combined as a single member will produce a beam several times stronger than the same quantity of materials not so combined. Increased stiffness is secured, thus reducing deflections and vibration. It was found that adding the concrete to the timber produced a beam nine times more rigid than the original timber.

Rough timber may be used, resulting in a twofold saving. The strength is greater and the cost may be reduced somewhat by avoiding the surfacing operation. It was found that the irregular dimensions of the unsurfaced material are not objectionable, since the plasticity of the fresh concrete allows for the irregularities.

Form cost is small by reason of the small amount of form work required, the simplicity of the forms, and their adaptability to reuse. This is brought about by the fact that the timber provides the strength to carry the dead load while the concrete is setting.

The conclusion is drawn, however, that this study can not be regarded as completed. There are some factors which can be determined only by the actual use of this type of construction for long periods of time or else by exhaustive experiments.

Infiltration Through Plastered and Unplastered Brick Walls, F. C. Houghten and M. Ingels (Journal American Society of Heating and Ventilating Engineers, 33 (1927), No. 4, pp. 249-258, figs. 8).—Studies are reported from which the conclusion is drawn that infiltration is a large factor in the total heat loss through an unplastered brick wall. The infiltration loss amounts to from 30 to 40 per cent of the total heat loss through such a wall. It was found that plaster either when applied directly on the brick or with furring and lath is very effective in reducing heat loss by infiltration. Paint will reduce infiltration through a plastered wall to a small per cent of its original value. However, its effect in conserving heat is relatively unimportant.

AGRICULTURAL ENGINEERING

Established 1920

A journal devoted to the advancement of the theory and practice of engineering as applied to agriculture and of the allied arts and sciences. Published monthly by the American Society of Agricultural Engineers, under the direction of the Publications Committee.

PUBLICATIONS COMMITTEE
S. H. McCrory, Chairman
R. W. Trullinger G. W. Iverson
J. B. Davidson F. A. Wirt

The Society is not responsible for the statements and opinions contained in the papers and discussions published in this journal. They represent the views of the individuals to whom they are credited and are not binding on the Society as a whole.

Contributions of interest and value, especially on new developments in the field of agricultural engineering, are invited for publication in this journal. Its columns are open for discussions on all phases of agricultural engineering. Communications on subjects of timely interest to agricultural engineers, or comments on the contents of this journal or the activities of the Society, are also welcome.

Original articles, papers, discussions, and reports may be reprinted from this publication, provided proper credit is given.

RAYMOND OLNEY, Editor

To Legislate Or Not to Legislate

PERHAPS in other branches of engineering more than our own the opinion has been rather freely expressed that engineers should enter politics, or engage in political activity, not as a career more profitable or honorable than straight engineering, but to give to our legislative halls and executive offices the benefit of the engineering attitude. Insofar as this will be the sole purpose and effect of the engineer's invasion of politics, we are inclined to favor the proposal.

But at the same time it is our firm conviction, based on a dispassionate view of the trend of late years in American government, that there is an opportunity, even a duty, for the engineer to render a service higher than the contribution of technical talent. It involves his attitude toward legislative and administrative policy whether the subject matter lies within or without his special field.

It is an old and now neglected axiom that the nation governed least is governed best. As a people we have more and more tried to bring every phase of human activity and relationship under governmental control. We have tried to confer on government the functions of church and school. We have sought to write into the statute books our moral code, our religions tenets, our economic theories, and much of our technical literature. By usurping the functions of other social agencies government has weakened them and embarrassed itself. De do not deny the landable, though sometimes misguided, purposes back of this mania for more and more government. We do deplore the futility and the fatuousness of trying to extend government beyond its logical and legitimate boundaries, with the burden of taxation and the cheapening of respect for government which follow inevitably. There are too many barnacles on the ship of state. As engineers we should use our influence, not to add more barnacles but to scrape off what there are, plug the leaks in the hull and improve the efficiency of the engines.

Herbert Hoover, the pioneer engineer in politics, has been cited so often that he is threadbare as an example of this, that and the other, but we must refer to his leadership in the matter of simplified practice as signifying an about-face from the fallacy of legislative panaceas. In all this simplification work he has striven to steer away from the legislative chambers, and has enunciated the doctrine of self-regulation in industry.

As the agricultural engineering profession progresses there will evolve codes of practice in farm home plumbing; farmstead electric wiring; fire-protective specifications for chimneys, water systems and building construction; principles of farm sewage disposal, and so forth.

Viewing each one as an isolated matter, unrelated to the underlying fabric of political science, social institutions, and human nature, it may seem wise to give each such code and specification the force of legal enactment. But in broad perspective it is obviously better to keep these things unsullied by the hand of the politician. They will command more respect, and more observance in spirit as well as letter, if promulgated simply as the findings of engineers. It is especially true of the agricultural public that it would rather adopt good practice of its own free will than by the oppression of authority.

It is long accepted in political science (not practical politics, so-called) that in successful government—popular government, at least—law can only follow and express a well-nigh unanimous public will. The extent to which law fails of respect and observance is the measure of the degree in which this basic principle is violated. The engineer and technician should be leaders and teachers of public opinion. But if they take resort to law they can be but followers, driving the recalcitrant stragglers after the main procession has marched on. It is neither practicable nor desirable to march the whole line by the snap of the legislative whip.

It seems, therefore, that engineers in general, and agricultural engineers in particular, should be exceeding loath to urge, or even sanction, taking the lazy man's legislative short-cut in regard to technical matters. Summed up, our proposal is:

"Engineers in politics, but no politics in engineering."

Farm Features for Farm Homes

OUT of twenty years of architectural experience has come one outstanding conviction—that the truly successful house plan cannot be found; it must be made. And six years in charge of building work for the California State Land Settlement Board convince me that this is just as true of the farm home as of any other.

But it does not follow that there is no distinctive architectural technique for the farm home. On the contrary, one of the most constructive things which we as agricultural engineers, and particularly as farm home specialists, can do is to establish and set forth the special needs and features of farm homes. If we can accomplish nothing more than to identify definitely in the minds of all concerned the requirements of farm houses as distinguished from those of city and suburban dwellings, we shall have made worthwhile progress.

Of plan books we have a sufficiency, and they may be helpful to the home builder, but they certainly do not prevent mistakes, the most serious of which, in my estimation, is the adoption of a city house plan for the farm. To the degree that we can offer rules or principles to serve as guides in making individual farm home plans or even to serve as something of an intelligent criterion in the selection of ready-made plans we may be sure that our efforts toward better farm homes are successful.

MAX E. COOK

Flood Control

IN THE face of the greatest flood catastrophe this country has ever known, and perhaps the greatest of all disasters we have ever experienced outside of war, engineers must assume the responsibility of solving the problem of river and flood control in a way that will prevent in the future the tremendous losses that occurred in the Mississippi basin this year. Obviously, it is an engineering problem, and American engineers will be equal to the task before them.

The solution of the problem, however, will not be complete with the building of higher levees, spillways, or reservoirs. In addition there is needed provision for preventing a too rapid run-off of snow water and rainfall. This calls for the terracing of sloping fields, reforestation, and forest fire prevention. It is this phase of flood prevention which, in the

final analysis, is perhaps the most important of all. Also it is this phase in which the agricultural engineer is particularly interested and where he can render effective service.

In any consideration of flood control measures, special attention must be given to such measures as are effective in controlling floods at their source, that is, on our farm lands. Obviously this phase of the problem is the most difficult as it involves dealing with owners of land, who must be convinced of the public need and the benefits to themselves of controlling the run-off.

In applying himself to the problem the agricultural engineer will not only be aiding in preventing flood disasters and consequent loss of property and life, but he will also be rendering the agricultural industry an outstanding service when he has provided measures which result in retaining valuable fertilizing elements in the soil and in otherwise contributing to the conservation of our soil resources.

That agricultural engineers are alert to the problem before them is evidenced by the resolution signed by the president and secretary of this Society and forwarded to President Coolidge urging the establishing of a board of engineers to make a survey of the problem and render a report for the guidance of Congress in passing appropriate legislation providing for control measures.

"Rub a Dub Dub"

SEVERAL years ago I was invited to inspect some examination papers submitted by seniors in agriculture in a final test in a course in farm mechanics. Instead of asking the stereotyped "end questions" in the course, the instructor "sprung" a test on practical farm problems. He asked such questions as: How many acres are there in a rectangular field of given dimensions? How many gallons will a cylindrical tank of specified size hold? Less than twenty per cent of the class—an average class—could correctly answer seventy per cent of the questions, and quite a number gave up without even trying.

There is something wrong! When a boy spends four years in high school and four years in college in preparation for farm life and then does not know how to attempt to "reason out" some of the simple problems of the farm, there is something wrong with the educational system.

Years ago when I was "taking the course" in farm machinery, I spent regularly some hours per week with "the mower, the raker, the bundlequick-maker" in a rub-a-dub-dub attempt to learn something of the mechanics of farming. It was, I believe, as good a course as was then given. The question sheet was the backbone of the course. The goal of the squads was to see which could count the bolts and measure the wheels fastest in order to make an early getaway. My most profitable recollection of that course is a field problem in testing the draft of a plow. If I do not remember the pounds pull of that plow, I at least acquired the idea that not all plows pull the same, and that the same plow requires varying amounts of power with differences in adjustment.

The very name "Farm Machinery I" or "Farm Machinery II" which has been handed down from year to year by force of habit suggests a multitude of questions, which when answered, are ended. Nor is "Farm Machinery" the only course in the agricultural curriculum which consists of "counting the bolts," "learning the chacteristics" or the assignment of "pages 37 to 52." Until a man learns to think and reason, he is fitted for little more than ordinary labor, although his brain may be a veritable storehouse for information.

Would it not be worth the revolution to attempt some courses in "Mechanical Field Problems" and "The Mechanics of Processing and Storing Crops" in distinction to "Farm Machinery" and "Farm Buildings?". The first object in such courses would be to discover the problem; the second to analyze that problem; the third step would be to attempt a solution, at which point we might arrive at the study of some existent or nonexistent farm machine, or process, and finally with the solution conceived, it could be applied practically to farm use.

Most of us agree that the business, marketing, and mechanical methods of father and grandfather are, at least in part, headed for the discard. The supplementing of these handed-down methods with a study of textbook compilations and laboratory exercises appears not to be the solution of the difficulty. The farmer who is making good today is one who is not so involved in rules-of-thumb that he lacks imagination and fails to grasp an opportunity; who can analyze a situation and reason out a solution from fundamentals; who can take his place on the farm, not as a plodder but as a thinker with ability to decide and act.

Engineering training should develop these qualities. What loss if we skip an exercise or a course and develop a real farmer?

GEO. W. KABLE

The Horicon Marsh In a Hundred Words

GIVEN a horseshoe four miles wide and seven miles long, enclosing 16,000 acres of low marsh and radiating 12,000 acres of higher marsh. That, fringed by the best farms of Dodge County, Wisconsin, is a picture of the Horicon Marsh.

Rock River enters the open end of the shoe and flows in a straight canal unobstructed until it strikes the Hustisford Dam protected by law, six miles below the toe calk.

This dam keeps the low marsh too wet for corn and the canal has made it too dry for ducks. Neither farmers nor hunters are satisfied. Hence, the battle of words.

Now the agricultural engineer suggests a ditch and dike in the track of the horseshoe, restoring the power dam at the toe calk, and draining the higher marsh into the canal below the dam.

This happy horseshoe would enclose a hunter's paradise, protect a border of cornfields, and generate electricity to help pay the bill.

Thirty states have similar drainage problems that can be solved only by intelligent agricultural engineering. Boy, page the president of the Izaak Walton League of America.

E. R. JONES

From India

Secretary, A.S.A.E.:

I AM returning to the U. S. A. on furlough and expect to spend the next school year in further studies at the University of Missouri. I have had a very interesting five years here in India. The Allahabad Agricultural Institute has had a large building and development program, and I have had many requests from other mission institutions for help on their buildings. While structures was not the subject in which I was most interested, I have had so much work in this line that I hope to write the thesis for my professional degree on the subject "Better Small Dwellings in India."

The question of buildings is one which has not even been touched as yet and there is room for enormous improvements. The common type of farm and village buildings is mud walls with a roof made of small clay tile laid on a mat of bamboo tied together with a cheap grass rope. This deteriorates and has to be repaired at the rate of about 15 to 20 per cent of the first cost every year. We have been able to develop a type of reinforced concrete roof which, while being permanent, can be built for practically the same cost as the old style temporary tile roof. While my main work has been supervision and teaching here at the Institute, I have designed on an average each year buildings worth from $25,000.00 to $30,000.00, and a large part of these buildings have been constructed under my more or less direct supervision.

I am looking forward with considerable anticipation to the privilege of meeting you and other members of the Society while in the states. Unfortunately I will not be able to get to the annual meeting this year, as I will not land in San Francisco until June 27, but I hope to be able to attend the meeting next year.

I hope to be able to send you before I leave India the application of my assistant, Deptimay Haldar, for membership in the Society.

MASON VAUGH

Professor of agricultural engineering
Allahabad Agricultural Institute
Allahabad, India

A. S. A. E. and Related Activities

A.S.A.E. Urges Prompt Action on River Control

THE havoc wrought this spring by floods along the Mississippi River, unparalleled in the history of this country, has brought seriously to the attention of the entire nation the necessity of effective measures to prevent a recurrence of this sort of thing in the future. While in a general way it is a problem for the entire nation, it remains for the engineers to provide ways and means of preventing such wholesale destruction flood waters as has occurred this year.

Agricultural engineers are especially interested in the problem of flood and river control, not only from the standpoint of their desire to be of service in connection with preventing the destruction of life and property by floods, but particularly because effective river control measures involve an engineering program that in addition to minimizing the effect of floods also results in retaining valuable elements of the soil on the farms where they belong. Therefore, as indicating its interest in the river control problem now before the nation and its desire to be of service in connection with its solution, the American Society of Agricultural Engineers has recently submitted to President Coolidge the following resolution, urging the appointment of a board of engineers to conduct a thorough study of the problem:

"WHEREAS an urgent need for effective river control has been brought to the attention of our citizens through the recent Mississippi River catastrophe, and

"WHEREAS the demand for effective flood control of rivers has assumed the aspect of a national problem, and

"WHEREAS the effective control of floods involves engineering knowledge and design and remains an engineering problem, therefore be it

"RESOLVED that the American Society of Agricultural Engineers respectfully and urgently requests the President of the United State of America, the Honorable Calvin Coolidge, to appoint at once an engineering board of seven properly qualified engineers to conduct a thorough study of the Mississippi River problem and make a report to the next Congress for its guidance in adopting a proper and effective method of river control, and be it further

"RESOLVED that a copy of this resolution signed by the President and Secretary of the Society be transmitted to the Honorable, the President of the United States of America.

"AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS

"OSCAR W. SJOGREN, President

"RAYMOND OLNEY, Secretary"

June 1, 1927

Coming A.S.A.E. Meetings

THE next outstanding event on the meetings calendar of the American Society of Agricultural Engineers — the premier annual event in agricultural engineering circles— is the 21st annual meeting of the Society to be held at University Farm, St. Paul, Minnesota, June 22 to 25.

Recently the Council of the Society approved dates for the winter meetings of the Farm Power and Machinery Division and the Farm Structures Division. Both meetings will be held at the Hotel Sherman, Chicago, during the week of the International Livestock Show, when special reduced railroad rates from most parts of the country will be in force. The meeting of the Farm Power and Machinery Division will be held Tuesday and Wednesday, November 29 and 30, and the meeting of the Farm Structures Division will be held Thursday and Friday, December 1 and 2.

The North Atlantic Section of the Society will hold a meeting at Pittsburgh, Pennsylvania, probably the second week in October. The dates for this meeting have not been definitely fixed.

The Southern Section will meet at Memphis, Tennessee, February, 1928, in connection with the annual meeting of the Southern Agricultural Workers Association. It is possible that this meeting will be a joint meeting between the Southern and Southwest Sections of the Society.

Result of College Division Election

AN ELECTION held last month for two members of the Advisory Committee of the College Division, to fill the vacancies on the Committee caused by the expiration of the terms of J. B. Davidson and H. H. Musselman, resulted in the election of E. R. Jones, professor of agricultural engineering, University of Wisconsin, and E. W. Lehmann, professor of farm mechanics, University of Illinois. Other elective members of the Committee, whose terms do not expire until June 1928, are C. I. Gunness, professor of agricultural engineering, Massachusetts Agricultural College, and M. L. Nichols, professor of agricultural engineering, Alabama Polytechnic Institute.

Personals of A.S.A.E. Members

W. T. Ackerman, project leader of the New Hampshire project on the Relation of Electricity to Agriculture, is author of bulletin No. 228, entitled "Electricity On New England Farms," just issued by the New Hampshire Agricultural Experiment Station. It is a report of the New Hampshire project for the years 1925 and 1926.

Frank Adams, professor of irrigation investigations and practice, University of California, left recently for several months work in Palestine as a member of an American commission to study the Zionist colonies.

Frank P. Hanson has resigned as extension specialist at the University of Illinois to become associated with the Western Harvester Company, Stockton, California. He will devote his attention to sales work in the territory east of the Mississippi and Missouri Rivers.

Stanley F. Morse, consulting agricultural engineer, who recently returned from an inspection trip to British Guiana, sailed May 12 for Colombia, South America. Mr. Morse will make an agricultural survey of a new region in the Department of the Cauca Valley.

W. K. Winterhalter, consulting agricultural engineer of San Francisco, is on a trip to Europe where he will make a survey of the British beet sugar industry, visit the Rothamsted Agricultural Experiment Station, and make a survey of agricultural research in Germany, Czechoslovakia, and Poland, where he will spend some time on the beet seed plantations and breeding laboratory of Messrs. Buszczynski & Sons in Cracow.

New A.S.A.E. Members

James Leonard Clark, secretary and treasurer, Clarke Publishing Co., Madison, Wisconsin.

Cecil Leon East, extension engineer, Penn Central Light & Power Co., Altoona, Pennsylvania.

Maximillian Fleischer, secretary and general superintendent, Inglewood Farms, Inc., Gordonsville, Virginia.

M. F. McCarty, branch manager, International Harvester Co., Aurora, Illinois.

John Q. McDonald, agriculturist, Caterpillar Tractor Co., San Leandro, California.

Willis L. Towne, advertising executive, General Electric Co., Schenectady, New York.

Transfer of Grade

Harris Pearson Smith, teaching, Texas A. & M. College, College Station, Texas. (Associate to Member.)

Robert Holcomb Smith, head of department of farm mechanics, New York State School of Agriculture, Canton, New York. (Associate to Member.)